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MACHINES FOR MAKING ICE, USING SULPHUROUS ACID OR AMMONIA IN THE PROCESS.

NOTE FROM THE ESTABLISHMENT OF RAOUL PICTET & CO., PARIS.

Translated by Robt. Briggs, C. E.*

The result accomplished by a machine in making ice and its corresponding expenditure of force can be investigated as follows:

In order to ascertain with exactness the useful effect of a freezing machine it is needful first to establish the theoretic maximum effect which it can produce, and then make a comparison of ideal result with what may be derived in practice.

[The difference between the theoretic and experimental results will represent the losses incident to the mechanisms employed and to the process followed; being in one case loss of power from friction of parts or of heat from radiation from the apparatus, and in the other the heat expended and transmitted over and above that absolutely demanded for mechanical effect or required to be removed for refrigeration. These losses are grouped in the original under the appellation of "passive efforts."]

* The paragraphs in [brackets] are amendments or additions to the original.

1st. When making ice by any process whatever, it is indispensable to take up the quantity of heat which is set free by the congelation of water, and to carry that quantity of heat to water having the temperature of the surrounding air, which temperature is always above the point of freezing, and generally varies between + 10° and + 30° centigrade.

[Throughout this translation metric values for temperatures and quantities of all kinds will be used.]

2d. The mechanical theory of heat furnishes a general formula, which expresses the maximum of labor to be expended in obtaining this result. Calling q = a certain quantity of heat which is made to pass from the lower temperature = t to a higher one = t', and calling J = the mechanical equivalent of heat, equal to 431 kilogram-metres, we have:

$$q\,\frac{t'-t}{274°+t}\,J = \text{labor necessary.}$$

[This formula may be elucidated in the following way. The physical phenomenon on which all the machines for ice making is based is the relation of the sensible heat of gaseous bodies to their densities. A gas, having a sensible temperature below the freezing point of water, is permitted to take up a certain quantity of heat of refrigeration of water. It is then compressed by mechanical force until it shall have attained some given temperature above that of a water supply at the disposal of the apparatus, the water from which shall now take up and carry off the quantity of heat originally imparted to the gas, when the gas being permitted to expand (and in a perfect apparatus to give out its force of expansion to the machine) to its original density, it will be prepared to receive another charge of heat, and the complete cycle of operation will have been established.

Let Q be the quantity of heat present in a definite volume of the transfer medium—the gas—at the time when it is in condition to absorb the heat of congelation; let q be the quantity of heat imparted to the transfer medium by the congelation; then $Q + q$ = quantity of heat in transfer medium at some definite condition of energy, and sensible temperature = t which is to be elevated by mechanical effort to t' for the purpose of allowing q to pass off. Let the weight of the medium employed = W; then W, multiplied by the absolute temperature of the medium, at any sensible temperature whatever, represents the quantity of heat present at that temperature.

$$\therefore \quad W\times(274°+t)=Q+q \text{ at the temperature } t. \qquad (1)$$

$$W\times(274°+t')=Q+q+H \quad \text{“} \quad t'. \qquad (2)$$

where H = the increment of heat in passing from t to t'.

$$\therefore \quad H=W[(274°+t')-(274°+t)]=W(t'-t)$$

and as from (1) $W=\frac{Q+q}{274°+t}$ $\therefore$ $H=\frac{(Q+q)\,(t'-t)}{274°+t}$

Now, if the transferring medium parts with the quantity of heat q at the temperature $=t'$, and then is permitted to expand to its primary condition, and is made to give back by its expansion, the force of expansion, which is applied to the retrograding piston of the air or vapor pump, it will, when it reaches the first temperture $=t$, have given out force represented in heat units by $H'=\frac{Q+(t'-t)}{274°+t}$ and the difference between the number of heat units expended in compression and those developed by expansion $=H-H'=\frac{Q+q\,(t'-t)}{274°+t}-\frac{Q(t'-t)}{274°+t}$ $=q\,\frac{(t'-t)}{274°+t}$, representing the units expended in the cycle of work.

Whatever mechanical effort may have been expended in the act of transfer of heat from the water to the medium, during the congelation in its certain time, will be compensated for, in the transfer which occurs from the medium to the water for removal of heat, at the higher point of temperature. The same quantity of heat $=q$ having to be taken up and given out in constantly recurring intervals of time—practically in the same times.

Multiplying the heat units by the mechanical equivalent $=J$, we have Pictet's formula: $q\frac{t'-t}{274°+t}J=$ mechanical effort.]

Suppose we would make 100 kilos. of ice per hour with water of 20°. Each kilo. of ice in such case will represent 79+20=99 calories. In order to estimate the force in horse-power, replace the letters by the following figures:

First, on the supposition of complete and instantaneous transfer of heat

$t=0°$ temperature of congelation.

$t'=20°$ temperature of water of supply both for congelation, and for removal of surplus heat.

$J=431$ kilogram-metres $=$ mechanical equivalent of heat.

One horse-power $=270{,}000$ kilogram-metres per hour.

$\therefore$ $100\times99\times\frac{20°-0°}{274°+0°}\times431\div270{,}000=1{\cdot}154$ horse-power.

Second, for the machine with sulphurous acid there must be 10° difference of temperature at both extremes of the process between the water used, for congelation on the one hand, or for removal of excess of heat on the other, when

$t = -10°$ temperature transferring medium when vaporizing.
$t° + 10° = t' = 30°$ " " " to be condensed.
other values being as before (when $t°$ = temperature of water = 20°).

$$\therefore \quad 100 \times 99 \times \frac{30° - (-10°)}{274° + (-10°)} \times 431 \div 270{,}000 = 2{\cdot}4 \text{ horse-power.}$$

With the water at 10° $\therefore t = -10°$; $t' = 20°$, and each kilo. of ice representing $79 + 10 = 89$ calories.

$$\therefore \quad 100 \times 89 \times \frac{20° - (-10°)}{274° + (-10°)} \times 431 \div 270{,}000 = 1{\cdot}618 \text{ horse-power.}$$

[The following table gives several numerical values to be applied in the formation of a scale which will exhibit graphically all the results from the formula:

TABLE OF COMPUTATION OF THEORETIC FORCE, in horse-power, demanded in making ice from water of various temperatures, on the

Degrees Fahr.	$t°$ = Temperature of the water.	$79° + t°$ = Latent & sensible heat to be removed.	$t' + 10° + 20°$ = Range of temperature to effect removal.	Absolute heat removed. $= \frac{t' + 10°}{264°}$	$= x$ Theor'c horse-power demanded for 100 kilos. per hour.	Computed horse-power, $= x + 20$ per ct. x.
	Degrees.	Degrees.	Degrees.			
14	—10	69	10	0·0379	0·418	0·502
23	— 5	74	15	0·0568	0·672	0·806
32	0	79	20	0·0758	0·958	1·150
41	5	84	25	0·0947	1·273	1·528
50	10	89	30	0·1136	1·618	1·942
59	15	94	35	0·1325	1·993	2·392
68	20	99	40	0·1515	2·400	2·880
77	25	104	45	0·1704	2·835	3·402
86	30	109	50	0·1894	3·303	3·961
95	35	114	55	0·2083	3·800	4·560
104	40	119	60	0·2273	4·328	5·194

supposition that the transfer medium be brought to 10° below the point of congelation for its lower temperature, and be carried to 10° above the water for removal of heat for its higher temperature, in order to effect the operation in a given time and against losses of heat.

$$\text{Formula: } x = (L + t^\circ)\frac{q\,(t' - t)}{274^\circ + t} \times J$$
$$270{,}000$$

where L = latent heat of congelation = 79°; q = quantity of ice per hour = 100 kilos; t° = temperature of water, variable; $t = 10^\circ$ below point of freezing = -10°; $t' = t^\circ + 10^\circ$, variable; J = equivalent of heat = 431 calories.

$$\therefore\ x = (79^\circ + t') \times \left(\frac{t' - (-10^\circ)}{264^\circ}\right) \times \left(\frac{100 \times 431}{270{,}000}\right)$$
$$= 0{\cdot}16 \times (79 + t') \times \left(\frac{t' + 10}{264}\right)$$

Referring to the plate accompanying this paper, the line *A* represents the theoretic results of a machine using sulphurous acid. The abscissæ are the temperatures and the ordinates the corresponding forces in horse-power.]

3d. These results can be compared with the performance of the ice machine in the present Exhibition at Paris, the dimensions of which are as follows:

Stroke of piston or steam cylinder = 1 metre.
Diameter of " " = 50 centimetres.
Pressure of steam = 5 kilos.* per sq. centimetre.
Point of cut off of steam in cylinder = 10 centimetres.
Back pressure in steam cylinder = 0.15 kilos. per sq. centimetre.
Stroke of piston in cylinder for compression of sulphurous acid = 1 metre.
Diameter of cylinder for compression of sulphurous acid = 42 centimetres.
P = pressure at the time of expiration, 0·8 kilos. per sq. centimetre.
P' = " " compression, 2·7 kilos. "
Velocity, 30 to 32 turns per minute.

In "Claudel's formulas," will be found (¶s 356—372, of Ed. 1857), for calculating the dimensions of condensing steam engines having a single cylinder with cut off, the formula for estimating the power given out is:

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*A kilogramme to the square centimetre = 14·22 lbs. to the square inch. An atmosphere = 14·7 lbs. per square inch, or 1·033 kilos per square centimetre. The horse-power, metrical value = 75 kilogram-metres per second = 270,000 kilogram-metres per hour = 1,052,971 lbs., in place of 1,980,000 lbs., the English value.

$$T_m = Vhk\left(1+\log.\left(\frac{z}{z_o}\right)\times 2{\cdot}3026-\frac{h'}{h}+\frac{z}{z_o}\right)$$

In this formula T_m = power given out in great dynamic units = 1,000 kilogram-metres—substituting for these their value in horse-power per second, we have

$$0{\cdot}075\ x = Vhk\left(1+\log.\left(\frac{z}{z_o}\right)\times 2{\cdot}3026-\frac{h'}{h}\times\frac{z}{z_o}\right)$$

which is the formula used in the original of this translation.

Where x = power given out in horse-power,

V = volume of steam per second of time, before cutting off, that is used under the full pressure h,

h = pressure of steam in metres of height of water = kilos. per sq. centimetre,

h' = back pressure in cylinder,

z = whole length of stroke in metres,

z_o = length of stroke to point of cut off in metres,

Vh = labor done before cutting off,

$Vh\ \log.\left(\frac{z}{z_o}\right)\times 2{\cdot}3026$ = labor done after cutting off.

k = co-efficient dependent upon resistance of engine, taken by M. Pictet at 0·73.*

substituting in the equations the values given, we have (taking the velocity at 30 turns per minute, or one stroke per second)—

$$0{\cdot}075\ x = \left[(0{\cdot}5^2)\times\frac{\pi}{4}\times 0{\cdot}1\times 5\times 0{\cdot}73\left(1+\log.\frac{1}{0{\cdot}1}\times 2{\cdot}3026-\frac{0{\cdot}15}{5}\times\frac{1}{0{\cdot}1}\right)\right]$$

$$0{\cdot}075\ x = [0{\cdot}196\times 5\times 0{\cdot}73(1+1\times 2{\cdot}3026-0{\cdot}03\times 10)]$$

$$0{\cdot}075\ x = 0{\cdot}7154(3{\cdot}3026-0{\cdot}30) = 2{\cdot}14807$$

$$x = 2{\cdot}87 \text{ effective horse-power.}$$

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* This value of 0·73 does not correspond to any value given by Claudel (edition 1857), where k has given many values, dependent on point of cut off, from 0·72 for ¼d to 0.84 for ⅛th; and also other values dependent on the size of engine, thus for several sizes of engines, all of which are supposed to cut off at one-fourth the stroke, the values given are from 0·44 for 4 to 6 horse-power to 0·74 for 60 to 100 horse-power. The co-efficient is purely empirical, and the value of the result in useful effect, derived from the computation, is not very satisfactory when it is considered that indicator cards could have been taken from the engine at the Exposition at any time.

[In the original, at this place there follows a computation of the force of compressing the gas in the compressing cylinder from 0·8 kilos. to 2·7 kilos pressure. It is impossible to accept this computation as the tension of vapor of sulphurous acid corresponding to 30°, the supposed maximum reached, or rather point of removal of heat, is 4·56 atmos. (= kilos. nearly), and the tension corresponding to 20°, the accepted temperature of the water, is 3·24 atmos. Probably the pressure P' was 3·7 kilos, but this value, used in the formula taken by M. Pictet & Co., gives a greater result in horse-power in the compression than was exerted in the steam cylinder. Indicator cards, with temperatures by observation, alone are reliable as practical data, and these are wanting to the above statements.]

The calculation of the weight of sulphurous acid evaporated at each stroke of the piston is as follows:

Density of sulphurous acid = 2·21

Weight per cubic litre, at 0°, = 2·88 grams.

$$\therefore \text{Weight} = W = \pi r^2 \times 1^m \times \frac{274}{274+t} \times 2{\cdot}88 \times 1000 \times 0{\cdot}8 \text{; taking } t = 0°$$

$$W = 0{\cdot}1385 \times 2{\cdot}88 \times 1000 \times 0{\cdot}8 = 319 \text{ grams.}$$

The useful effect of the compression being 90 per cent. between the limits of pressure named, this weight is reduced to 287 grams per stroke or half revolution of the engine.

The latent heat of evaporation of sulphurous acid is 94·5 calories per kilogram vaporized. The weight of ice formed per hour, independent of external losses by radiation or conduction, is:

$$\frac{287 \times 60 \times 60 \times 94{\cdot}5}{99} = 1{,}000 \text{ kilograms [977 exact result.]}$$

This machine makes 1,000 kilos of ice per hour, and employs 29 horse-power, of which only 22 is utilized in the labor of compressing the vapor of the sulphurous acid.

4th. In the plate, the curve C shows the maximum tension of the vapor of sulphurous acid at the temperature given by the abcissa, as ascertained by M. Regnault. [In the original paper it reads, "The temperature corresponding to 2·7 kilos 'effective' is 25°." This allusion would confirm the view of the translator that the pressure obtained in the compressor cylinder is 3·7 kilos. at least, but this rendering is fatal to the computation of power in the compressor as it appears in the original.

5th. If the value of power expended which has been computed from the formula of Claudel on the data given by M. Pictet & Co. be accepted as giving a correct result in the one particular instance to

compare with that derived from the theory of heat, the simple addition of 20 per cent. to any of the theoretic values will exhibit with much fairness the practical useful effect. Some economies may attach to the performance of the larger apparatus, but those may be held to belong to the sizes of apparatus rather than to the resistance to be overcome. The line *B* shows the horse-power deemed requisite by M. Pictet & Co. to make 100 kilos of ice per hour. But the translator is of opinion that these values are about 25 per cent. too small, or, in other words, that the best practical result will be about 50 per cent. above the theoretic one, as there is not only to be met "the work expended in friction of connecting rods, cranks, pistons, screws, centrifugal pumps, etc.", but also many considerable and quite unavoidable losses of heat.]

6th. It is obvious that the same methods of reasoning and the same calculations will apply to higher or intermediate temperatures.

7th. [The final result from these considerations indicates a theoretic expenditure of force in making 100 kilos. of ice, per hour, by means of ice machines using sulphurous acid, to be from 1·27 to 4·3 horse-power, in countries having the extremes of temperature of 5° to 40°, and, according to M. Pictet & Co., from 1·53 to 5·2 horse-power, or, yet again, for liberal allowance, from 1·9 to 6·5 horse-power in countries having the same relations in temperature.

8th. Using a condensing engine, the consumption of coal per horse-power and per hour can easily be brought to 1·5 kilo. An engine cutting off its steam at 1-10th the stroke, as assumed in this case, with boilers of average economy, say the burning of 9 kilos of coal to the kilo. of water evaporated, = to the production of 4,833 calories, should develop a horse-power with under one kilo of coal per hour. This assumption of a large value for the coal per horse-power is confirmatory to the expenditure of more power than was apparently given out by the computation. Taking the translator's estimate for horse-power demanded, and the assumption of engines and boilers with one kilo. of coal per horse-power per hour, we have, in countries where or when water at 5° is attainable, about 50 kilos. of ice to 1 kilo. of coal, while in the hottest supposable locality, where the water reaches 40°, 16 kilos. of ice can be made with 1 kilo. of coal burned. Accepting 30° as the temperature of water in a hot country, 100 kilos. of ice ought to proceed from the expenditure of 5 horse-power, and 20 kilos. of ice from the combustion of 1 kilo. of coal. The assumption of engines to cut off at one-tenth the stroke is, however, not generally admissible for any but the largest engines, and the allowance of 1·5 kilo. of coal per horse-power gives 13·3 kilos. of ice to each kilo. of coal burned, as a high practical result.]

9th. The use of water power will considerably reduce the cost of running an ice machine.

[It may be remarked, as a final result of the foregoing, that the economy of ice machines evidently depends, 1st, upon the small differences of temperature between the transfer medium above the cooling water, on the one hand, or below freezing point of water on the other. In the case where fluids are used which condense at temperatures and pressure within the range of the operation, it is possible that much heat may be given out to the cooling water above the point of condensation and a non-reversable cycle be set up; and the economy depends, 2d, on the economy of the source of motive power, that is, of the steam engine and boilers employed.]

Ice Machines using Ammonia.

10th. In considering this class of ice machines, it will be assumed that their construction and process in operation is known. The quantity of heat to be furnished to the boiler is composed of two entirely distinct parts, the first of which is that necessary to evaporate the ammonia in the freezer, utilizing the latent heat, while the second is the heat lost by escape of temperature through the transmission of the total amount of heat which has to traverse five heavy iron apparatus successively. This loss will be estimated at its maximum theoretic value.

11th. Taking for calculation the production of 100 kilos of ice between ordinary limits of temperature in warm countries, that is to say, condensation at $+30°$ and freezing at $-30°$, we have for the first source of expenditure of heat the loss, between a temperature of $+140°$ [corresponding to 16 atmospheres pressures] and $-30°$, which are the extremes of temperature between which the non-reversible cycle of operations is performed, = (taking the water at 20°)

$$9{,}900 \times \frac{140-(-30°)}{274+(-30°)} = 6900 \text{ calories.}$$

12th. And for second source of expenditure of heat—that of heat generated in the boiler, which is never returned, but is wasted in the process—we estimate the pressure in the boiler to be 16 atmospheres, which pressure shall be divided into:

4 atmospheres for steam,
12 " for the ammonia.

The distillations will occur proportionately to their maximum tensions, and then to remove 10,000 calories per hour [9,900, if the water

to be frozen is at 20°] there should be evaporated 10 kilos. of water and 31 kilos. of ammonia.

We have then to adjust these two quantities of heat in order to find the minimum amount to be furnished by the boiler. [The total heat of water vaporized at $+140° = 656$ calories.]

The total heat of ammonia at $+140°$ is 465 calories.

But the temperature of ammoniacal liquor with which the boiler is fed is 90°, which will reduce these figures to

566 calories for the water,
and to 411 " for the ammonia.

10 kilos. of water, at 566° = 5,660
31 " of ammonia, at 411° = 12,740 to which is to be added the theoretic loss as before computed = 6,900

25,300

There should be furnished 25,300 calories to the boiler as the least quantity to produce 100 kilos. of ice.

14. * * * [Supposing the consumption of fuel under the boiler is effected with average economy, as previously assumed, of = 9 kilos of water evaporated (4,833 calories) per kilo. of coal burned, we have:

$\frac{25,300}{4,833} = 5{\cdot}235$ kilos. of coal to the 100 lbs. of ice per hour, as the theoretic result without loss of heat in any way during the process. This result does not fairly represent the argument of M. Pictet & Co. The heat should be divided into two parts, as in the estimate. Of which 5,660 + 12,740 = 18,400 calories will proceed from application of heat of fuel to the boiler, when $\frac{18,400}{4,833} = 3{\cdot}8$ kilos of coal may be assumed to supply this heat. And the 6,900 calories which will have been expended in transferring 9,900 calories through a range of 170°, by exertion of mechanical force, may be taken (having been derived through the action of a steam engine and pump) to have been effected as economically as was assumed in the sulphurous acid process. In the sulphurous acid process, with water at 20°, we have the heat of transferring the heat of congelation $= 9,900 \times \frac{30° - (-10°)}{274° + (-10°)} = 1,500$ calories, and our previous estimate gives 2·4 horse-power as the theoretic force accompanying the same. When $\frac{6,900}{1,500} 2{\cdot}4 = 11{\cdot}04$ horse-power, which may be taken at 1·5 kilo. of coal per horse-power, as before (¶ 8th).

CURVES OF USEFUL EFFECT, ETC.

OF

ICE MACHINES USING SULPHUROUS ACIDS.

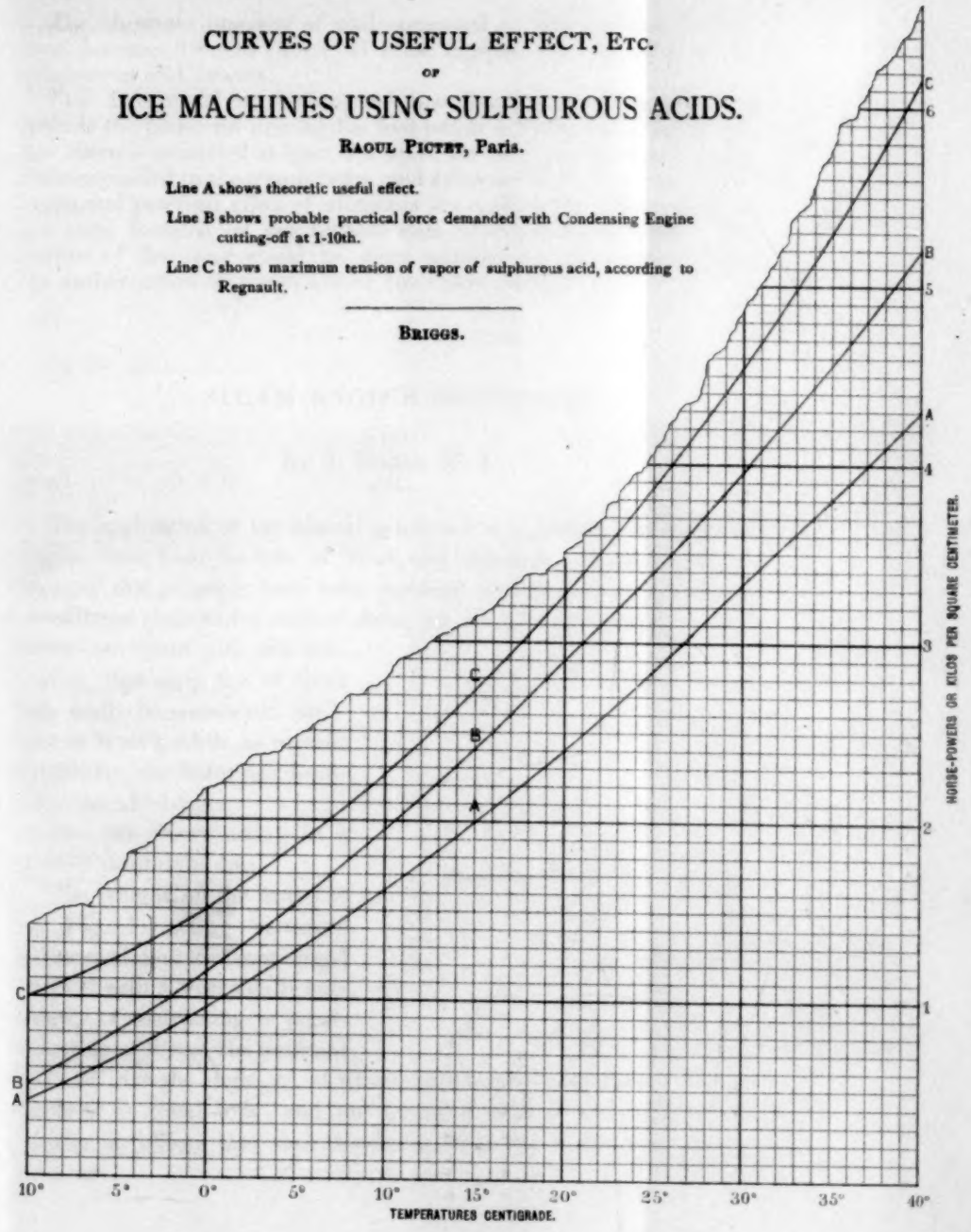
RAOUL PICTET, Paris.

Line A shows theoretic useful effect.

Line B shows probable practical force demanded with Condensing Engine cutting-off at 1-10th.

Line C shows maximum tension of vapor of sulphurous acid, according to Regnault.

BRIGGS.



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The theoretic quantity of coal consumed by the ammonia process then becomes 3·8+16·75=20·37 kilos. (against the 3·6 kilos. by the sulphurous acid process.

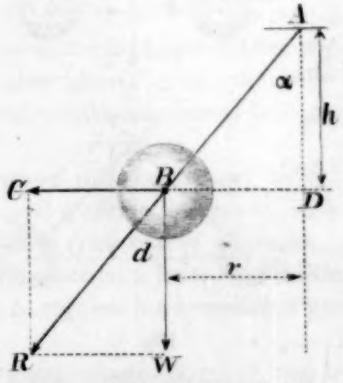
14A. It is noted in the original that the above estimate does not include the power for driving the feed pump or for agitating the liquid, and there is estimated at least 1·5 kilos. for these purposes and for the force expended in the transmission, and reference is made to lines of theoretic and practical effect of ammonia ice-making machines which do not seem founded on any reliable data or experimental basis. This portion of the paper would be more satisfactorily presented if it had the authorization of the maker of the Carré machine.]

STEAM ENGINE GOVERNORS.

By J. Haug, M. E.

The application of the conical pendulum as a governor to the steam engine dates from the time of Watt, and although countless modifications of this principle have been patented since that time, and certain advantages claimed for each of these, yet the general opinion of engineers conversant with this subject is, that only few of them can really be considered superior to Watt's, while, as regards simplicity, the latter has decidedly the advantage.

Fig. 1.



The two forces acting in a conical pendulum are:

The weight of the ball (*W* in Fig. 1) acting vertically downward, and the centrifugal force *C*, acting horizontally outward. Constructing a parallelogram of forces, the resultant *R* will give the angle α', at which equilibrium is attained. Then as angle α is equal to α', and the triangles *A B D* and *B R W* are similar, it follows that their respective sides are of the same proportion, or

$$\frac{h}{r} = \frac{W}{C} \qquad (1)$$

i. e., the height of suspension is to the radius of revolution as the weight of the ball is to its centrifugal force.

But the latter is:

$$C = \frac{(2\pi n)^2 r W}{g}$$

where n = number of revolutions per second and g = unit of gravity = 32·166 feet.

Introducing this term in Formula (1), we have

$$h = \frac{W g r}{(2\pi n)^2 W r} = \frac{g}{4\pi^2 n^2} = \frac{0{\cdot}81452}{n^2} \text{ in feet.}$$

or if n_1 = number of revolutions per minute,

$$h = \frac{2993}{{n_1}^2} \text{ in feet.} \qquad (2)$$

and

$$n_1 = \sqrt{\frac{2933}{h}} \qquad (3)$$

Fig. 2.

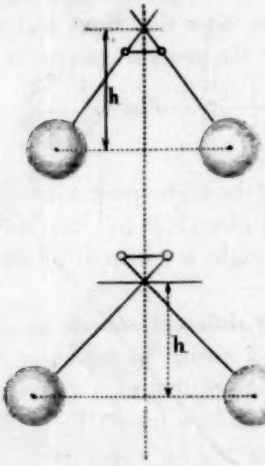
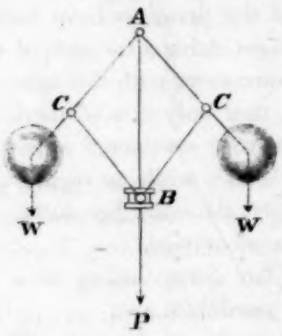


Fig. 3.

Fig. 4.



Wherever the joints of the arms may be situated, h is always the vertical distance from centre of ball to intersection of arm with the centre line of spindle, as shown in Figs. 2 and 3, which will be evident when it is considered that the centrifugal force is directly proportional to the radius of revolution.

In the above demonstration no account has been taken of the weight of arms and other gear connected with the governor.

Taking now (Fig. 4), $a\ A\ D, -b = A\ C$.

W = weight of ball + half the weight of suspension rod.

P = weight of collar B + weight of other gear not balanced.

Then
$$n_1 = \sqrt{\frac{2933}{h}\left(1 + \frac{P\ b}{W\ a}\right)} \qquad (4)$$

While the force exerted by P is added to the force W (Fig. 1) in proportion to its leverage, it cannot increase the centrifugal force, which, to attain equilibrium, has to be augmented by a greater number of revolutions, as obtained by Formula (4).

Fig. 5.

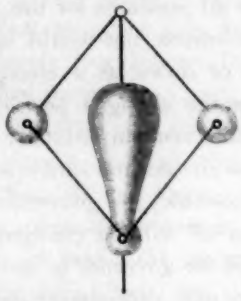
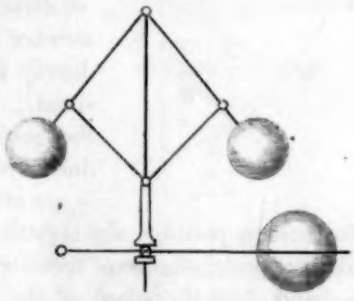


Fig. 6.



In Porter's governor, as first applied to the high-speed Allen engine, we find the extreme application of this idea (Fig. 5); the balls are made very small, and the heavy central weight is balanced by a greater number of revolutions.

In place of a central weight, springs of different shapes have been applied, but, owing to the resistance of a spring increasing with its deflection, its action is somewhat different from that of a weight.

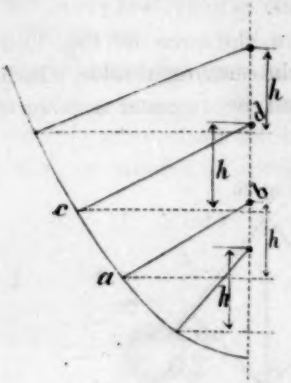
Fig. 6 shows the extra weight adjustable on a lever; by shifting it in or out the governor may be made to regulate for a smaller or greater number of revolutions.

The ordinary governor has the great disadvantage of not being isochronous or "equal timed"; at the normal speed of the engine, the arms can only be in one certain position, corresponding to a certain position of throttle or cut off. An increase or decrease of load will necessitate a change of throttle or cut off, and a corresponding position

of governor, which can only be attained by a proportional decrease or increase in the number of revolutions.

To overcome this difficulty, a great many isochronous governors have been brought out, of which the "parabolic" governor may be taken as *theoretically* perfect.

Fig. 7.



In a common parabola (Fig. 7), all "subnormal" lines, *i. e.*, the vertical distance h of the intersection of a line normal to the curve (as $a\ b$, $c\ d$, etc.) with the centre line from its intersection with the parabola, are equal, and if the centre of a governor ball moves in a parabola, such a governor would be in equilibrium at all positions for the same number of revolutions, but would immediately go up or down at a change of speed. If now the changed position of the governor does not immediately produce a return to the normal speed (which is not always possible) the governor will fly to its extreme position, the throttle or cut off will be changed too far, and an opposite change of speed will send the governor to its other extreme, and thus the speed of the engine will continually change above and below its normal speed.

Fig. 8.

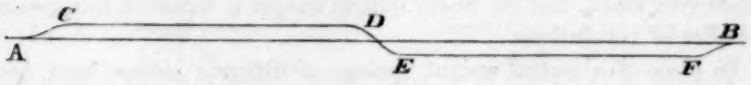


Fig. 9.

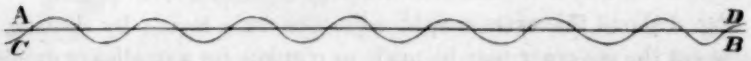


Fig. 8 illustrates graphically the action of the common governor: Line $A\ B$ represents the normal speed, $C\ D$ the increased speed, which, at a decrease of load, is necessary to keep the governor in a higher position, and this speed continues until an increase of load, requiring a lower position of governor (to effect corresponding change in throttle or cut off) makes a speed below the normal imperative, as shown

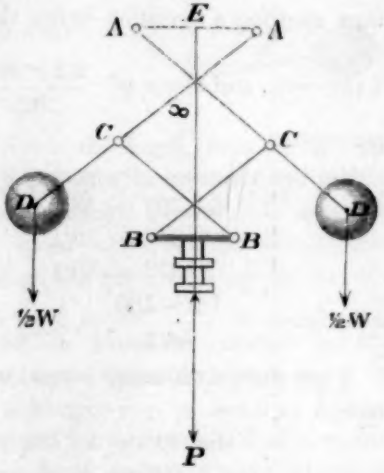
at *F E*, and this speed again continues until another change of load requires a different speed and position of governor, or until a return to the normal load again establishes the normal speed and position.

The action of an isochronous governor, as described above, may be graphically illustrated by Fig. 9; where *A B* is the normal speed and *C D* the continual change of speed above and below *A B*, produced by the instability of the governor. To remedy this defect, some kind of resistance, which could not be overcome too quickly, would have to be opposed to the action of the governor, but at the cost of sensitiveness; an air cushion (which should be double acting) would be least objectionable, as a spring, owing to its resistance increasing with its compression (and *vice versa*), would destroy the isochronous property of the governor.

By a very slight modification the Watt governor may be made sufficiently isochronous for most practical purposes.

If the arms are suspended on the opposite side of the centre line (Fig. 10), an approximation to the parabolic governor is obtained, *A* being the centre of a circular arc, which, for a movement through a few degrees, will nearly coincide with a parabolic curve, and therefore such a governor will be nearly isochronous.

Fig. 10.



To show the percentage of deviation, the following example is a comparison of the ordinary Watt (Fig. 4) with the last-named governor:

Taking the arms $A\,D = a = 20''$ long, $B\,C = A\,C = b = 10''$, the normal angle $\alpha = 30°$, the extreme angles $\alpha_1 = 20°$ and $\alpha_2 = 37°$, the lift of the sleeve will be, for all three systems of suspension, $= 2\,b\,(\cos.\,\alpha_1 - \cos.\,\alpha_2)$ consequently each will do the same work.

h will be for Watt's governor $= a \cos.\,\alpha$.

for 30° = 17·32 inches.
" 20° = 18·79 "
" 37° = 15·97 "

for improved governor : (taking $EA = BF = e = 2''$)

$$h = a \cos. \alpha - e \text{ cotg. } \alpha,$$

for 30° = 13,856 inches.
" 20° = 13·3 "
" 37° = 13.316 "

According to Formula (4), n_1 would then be, $\left(\text{if } \frac{P}{W} = \frac{2}{3}\right)$ for the ordinary governor—

for 30° = 52 rev. per min.
" 20° = 49·9 "
" 37° = 54·2 "

thus showing a deviation below the normal speed of $\frac{2{\cdot}1 \times 100}{52} =$ 4 per cent., and above of $\frac{2{\cdot}2 \times 100}{52} = 4{\cdot}2$ per cent., a total of 8·2 per cent.

For the improved governor n_1 would be

for 30° = 58·2 rev. per min.
" 20° = 59·4 "
" 37° = 59·4 "

a deviation of $\frac{1{\cdot}2 \times 100}{58{\cdot}2} = 2$ per cent.

A governor with arms jointed outside of centre line (Fig. 2) would have $h = a \cos. \alpha + e \text{ cotg. } \alpha$:

for 30° = 20·784 inches.
" 20° = 24·28 "
" 37° = 18·624 "

and n_1 would be :

for 30° = 47·5 rev. per min.
" 20° = 44 "
" 37° = 50·2 "

a deviation of $\frac{3{\cdot}5 \times 100}{47{\cdot}5} = 7{\cdot}35$ per cent below, and $\frac{2{\cdot}7 \times 100}{47{\cdot}5} = 6$ per cent. above the normal speed, a total of 13·35 per cent.

The last-mentioned construction is thus shown to be most deficient in isochronism, and many attempts have been made to correct this fault. One of the latest is the Gardner governor (Figs. 11 and 12), where a toe on the end of the suspension arm presses transversely against a toggle joint combination, which is connected to a weight or spring pressing upwards, thus tending to compress the toggle joint vertically, forcing it outward against the toes of the governor arms.

Fig. 11.

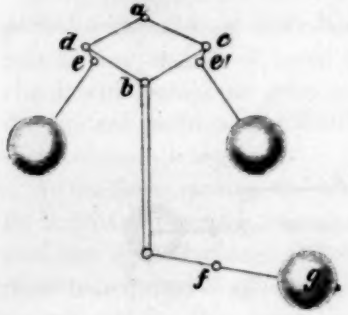
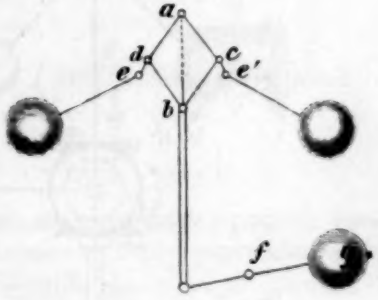


Fig. 12.



When the governor arms are down, the toggle joint being more compressed vertically, exerts greater pressure horizontally against the governor arms; to counteract this the centrifugal force must be increased by a few revolutions, bringing the speed nearer to the normal, and exactly the opposite action occurs, when the governor arms move above their normal position.

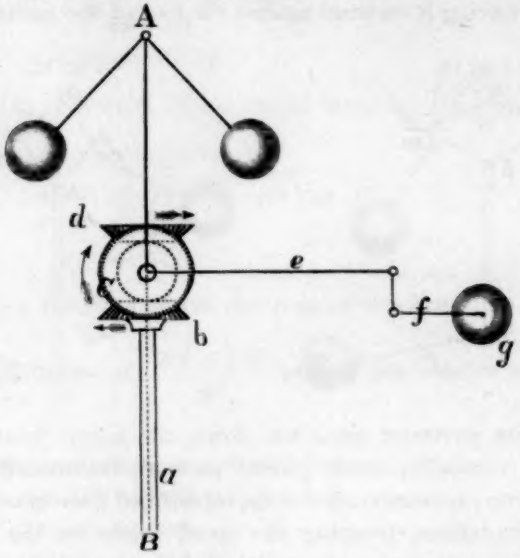
A recent test of this governor at the Franklin Institute gave a deviation of from 6 to 14 per cent. from the mean speed, hence its isochronism is very far from being perfect.

Siemens' differential or chronometric governor consists of a conical pendulum with heavy balls, driven by a train of bevel wheels, as shown in Fig. 13. The shaft *a* receives its motion from the engine, and has keyed on its end a bevel wheel, *b*, which gears into another similar wheel, *c*, that can vibrate around the vertical axis *A B*, but is held in position by the weight *g*, acting through lever *f* and rod *e*. The wheel *c* gears into the wheel *d*, which is fixed on the shaft of the pendulum, and thereby the latter is put into motion.

The weight *g* is adjusted to balance exactly the tangential force of weight *a*, necessary to drive the pendulum at the normal speed; if now

the engine (and with it shaft *a*) changes it speed, the pendulum, on account of its inertia, will still continue its uniform speed, which causes the wheel *c* to swing around the axis *A B*, and the lever *f* being fixed on a shaft connected with the throttle or cut off, these will be changed correspondingly.

Fig. 13.



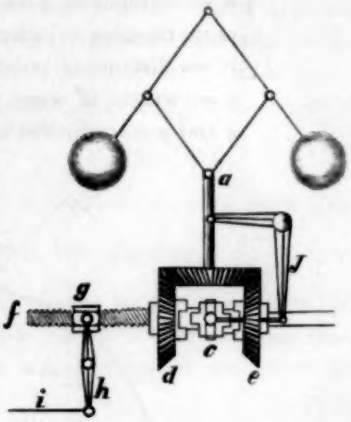
As the power necessary to drive the pendulum at a certain speed may be considered uniform, the wheel *c* will only be at rest as long as this speed is maintained, but (within a certain limited travel of lever *f*) it may be in different positions; and as thereby different positions of throttle or cut off, corresponding to the load to be overcome by the engine, can be attained without a permanent change of speed, the governor may be called perfectly isochronous.

As in some cases the shifting of throttle or cut off gear may require more force than a change in speed of the pendulum, the latter has an ingenious arrangement, by which a slight rise or fall of the pendulum balls will increase that force.

The ordinary Watt governor may act indirectly upon the throttle or cut off, as shown in Fig. 14. The sleeve *a* of the governor is connected by lever *j* to a clutch, *c*, which, being between two bevel

wheels, *d* and *e*, running in opposite directions, is put into gear with either by a rise or fall of the governor balls. This clutch slides upon a feather in the screw *f*, which, by means of nut *g*, lever *h* and rod *i*, can move the throttle or cut off.

Fig 14.



Here the governor acts with perfect isochronism, as it is evident that at any change of speed the clutch will remain in gear until the normal position and number of revolutions is regained.

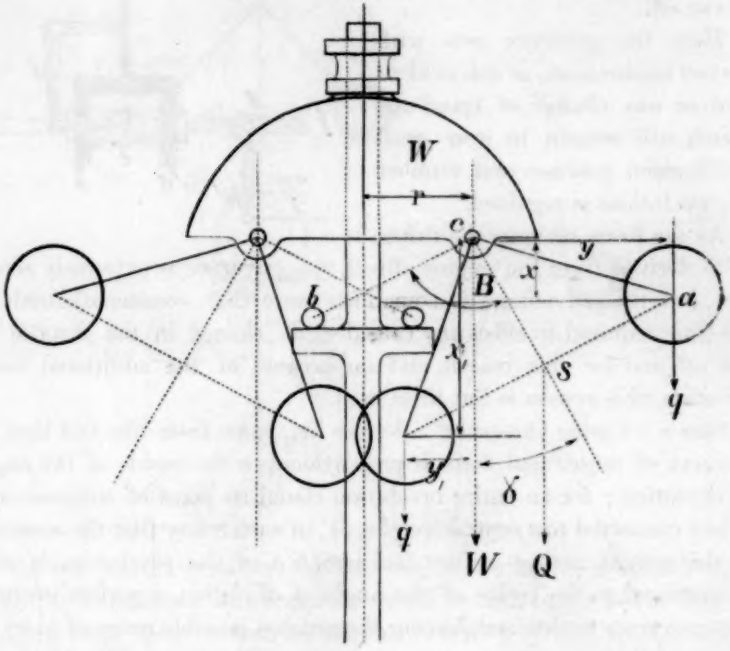
As the force moving the throttle is derived from the engine direct, the governor is extremely sensitive, but this advantage is sometimes more than counterbalanced by the time required to effect any considerable change in the throttle or cut off, and for this reason, and on account of the additional complication, this system is but little used.

Buss's "Cosine Governor" derives its name from the fact that its moment of centrifugal force is proportional to the cosine of the angle of deviation γ for an entire revolution round its point of suspension *c*. When connected to a central weight, *W*, in such a way that the moment of this weight, acting against an arm, *b c*, of the pendulum, is also proportional to the cosine of the angle of deviation, a perfect isochronous governor is obtained, having the greatest possible range of motion, consequently possessing great power and sensitiveness. Fig. 15 shows that each arm of the pendulum has two balls, fixed at 90° to each other, which are suspended from a point, *c*, situated in the central weight; the arms *c b* bear against a fixed shoulder on the spindle, and the centrifugal force of the balls has to balance both the central weight *W* and the weight of the balls, hence all parts are utilized to increase the power and sensitiveness. By a small change of the angle *s c b*, a nearly uniform degree of stability with only a limited deviation from isochronism can be obtained, thus obviating the most serious defect of isochronous governors—their instability.

The theory of this governor, as given by the inventor, is as follows:

If Q = total weight of a system of bodies suspended at c,
n = number of revs. per second; then
ω = angular velocity = $2\,\pi\,n$.
r = distance of point of suspension from axis of revolution,
q = weight of some part of Q,
x and y co-ordinates of q with regard to c,

Fig. 15.



The centrifugal force of q will be

$$c = \frac{\omega^2}{g}\, q\,(r + y)$$

and its moment $m_c = x\,\frac{\omega^2}{g}\,q(r+y)$ and the centrifugal moment of the entire system $M_c = x_1 \Sigma q\,\frac{\omega^2}{g}\,(r+y_1) = \Sigma q\,\frac{\omega^2}{g}\,x_1 r + \Sigma q\,\frac{\omega^2}{g}\,x_1 y_1$. (5)

If x_1 and y_1 are the co-ordinates of the centre of gravity of the entire system, $x_1 = \frac{\Sigma q\,x}{Q}$ and $y_1 = \frac{\Sigma q\,y}{Q}$ *i. e.* the distance of the com-

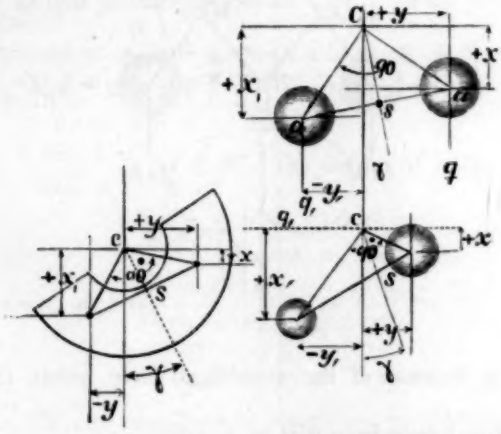
mon centre of gravity of a system of bodies from any point is equal to the sum of the moments of the parts with regard to this same point, divided by the sum of their weights.

If l is the distance $c\ s$, $x_1 = l \cos. \gamma$ and

$$M_c = \frac{\omega^2}{g} r\ Q\ l \cos. \gamma + \frac{\omega^2}{g} \Sigma\ q\ x_1\ y_1 \qquad (7)$$

If the weight of the revolving body is divided into such parts that their moments, $q\ x\ y$ and $q\ x_1\ y_1$ are equal, but opposite, $\Sigma\ q \frac{\omega^2}{g}\ x_1\ y_1$ (Formula 7) will be $= O$, and this will always be the case where the parts are at 90° and their moments, with regard to their common centre of gravity, s, are equal, of which some examples are given in Fig. 16.

Fig. 16.



In each of these cases (taking $f = c\ a$) : $q\ x\ y + q_1\ x_1\ (-y_1) = q\ f^2 \cos. (45+\gamma) \sin. (45+\gamma) + q\ f^2 \cos. (45-\gamma)\ (-\sin. 45-\gamma) = O$, hence $M_c = \frac{\omega^2}{g} r\ q\ l \cos. \gamma.$ (8)

i. e., proportional to the cosine of the angle γ.

In applying the central load, W, the weight of the balls, having the moment $= Q\ l \sin. \varkappa$, must be taken into account, and the angle $c\ s\ b = \beta$ will have to be so arranged that

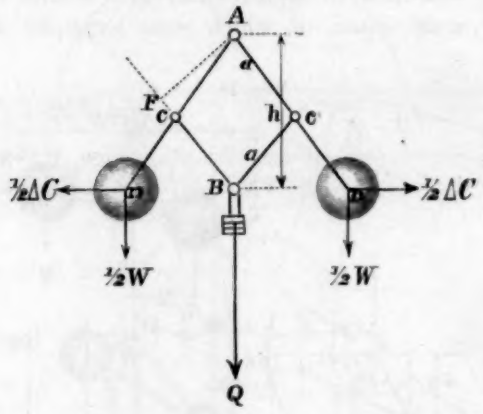
$$Q \frac{\omega^2}{g} r\ l \cos. \gamma = (W+Q)\ b \sin. (\beta-\gamma) + Q\ l \sin. \gamma,$$

to make the governor perfectly isochronous, and this is obtained by making

$$\cos.\ \beta = \frac{Q\ l}{(W+Q)\ b}$$

From Formula (2) it is apparent that theoretically the weight of the balls has no influence on the position or number of revolutions of a pendulum, as the centrifugal force increases in the same ratio with an increase of weight, but in its practical application this point is of some importance; to overcome the resistance of the gear there must be a cer-

Fig. 17.



tain increase or decrease of the centrifugal force before the governor can act.

If n = normal number of revolutions,
n_1 = lowest and
n_2 = highest number of revolutions permitted,

then $\delta = \frac{n_2 - n_1}{n}$ = total deviation.

For n the centrifugal force is:

$$C = (2\pi n)^2 \frac{W}{g} r$$

and for n_2:

$$C_2 = (2\pi n_2)^2 \frac{W}{g} r$$

and the difference:

$$A\ C = 4\ \pi^2\ (n_2^2 - n^2)\ \frac{W}{g}\ r$$

or, approximately:

$$\Delta\ C = \delta\ 4\ \pi^2\ n^2\ \frac{W}{g}\ r;$$

its leverage being $= h = \frac{g}{4\ \pi^2\ n^2}$,

its moment is:

$$\Delta\ C\ h = \delta\ \frac{4\ \pi^2\ n^2\ W\ r\ g}{4\ \pi^2\ n^2\ g} = \delta\ W\ r. \qquad (9)$$

If Q = resistance of gear referred to sleeve B,
$b = A\ C$,
$a = A\ D$,

this action of Q will produce a force $= \frac{Q}{\text{cos. } \alpha}$ in the direction of BC, which, with regard to A, will act with a leverage $A\ F = b$ sin. $2\ \alpha$, hence its moment $= \frac{Q\ b\ \text{sin. } 2\ \alpha}{\text{cos. } \alpha}$. (10)

Putting $Q\ \frac{b\ \text{sin. } 2\ \alpha}{\text{cos. } \alpha} = \delta\ W\ r$, the weight of balls is found:

$$W = \frac{Q\ b\ \text{sin. } 2\ \alpha}{\delta\ r\ \text{cos. } \alpha}.$$

and as $r = a$ sin. α, and $\frac{\text{sin. } 2\ \alpha}{\text{cos. } \alpha\ \text{sin. } \alpha} = 2$, $W = \frac{Q\ 2\ b}{\delta\ a}$

or each ball: $$\frac{W}{2} = \frac{Q\ b}{\delta\ a} \qquad (11)$$

showing that, for any considerable resistance, very heavy balls or an extensive deviation of speed from the normal, would be needed, to effect a change in the throttle or cut off gear.

A governor, loaded with a central weight (Fig. F.), has an advantage in this respect, as its greater angular velocity (necessary to balance the central weight) will give a greater differential moment of centrifugal force for a certain change of speed than the ordinary construction.

Here $h = \frac{g}{4\ \pi^2\ n^2}\left(1 + \frac{P\ b}{W\ a}\right)$ [see Formula (4)], making the differential moment of centrifugal force: $\Delta\ C h = \delta\ \frac{4\ \pi^2\ n^2\ W\ r\ g}{4\ \pi^2\ n^2\ g}\left(1 + \frac{P\ b}{W\ a}\right)$

$$= \delta\ W\ a \text{ sin. } \propto \left(1 + \frac{P\ b}{W\ a}\right) \qquad (12)$$

and putting this equal to the moment of resistance of gear:

$$= \frac{Q\ b \text{ sin. } 2\ \propto}{\text{cos. } \propto} \text{ will give}$$

$$W = \frac{Q\ 2\ b}{\delta\ a \left(1 + \frac{P\ b}{W\ a}\right)}; \qquad (13)$$

Thus if $\frac{P\ b}{W\ a} = 1$, the weight of balls will only be one-half of that needed for the ordinary governor, to overcome the same resistance, or balls of the same weight would already act at one-half the deviation of speed from the normal, thus doubling the sensitiveness of the governor.

In conclusion it might be well to point out that a sensitive governor is not the only thing necessary to ensure uniformity of motion.

Not only the load may be variable, but the pressure at different parts of a revolution also varies, especially in engines working expansively, and when the steam is cut off, the influence of the governor is cut off also, hence the fly-wheel ought to be heavy enough to store up any excess of work developed during that time, without greatly increasing the speed, otherwise the governor, especially if it is very sensitive, will always be flying up and down, thus defeating its very object.

Systematic Errors.—Otto Struve states that his measurements, especially those of direction, are subject to very large systematic errors, depending upon the angle between the direction of the two stars and the vertical circle at the moment of observation. By means of measurements taken upon artificial stars, he has determined the corrections with great exactness and has proved that the same laws of error have existed in his case for the last 35 years. He supposes that they have a physiological origin depending upon the construction of the observer's eyes. He thinks it desirable that every astronomer who is employed upon similar measurements should make special experiments so that the results of different observers can be more satisfactorily compared.—*Comptes Rendus.* C.

WATER-TUBE AND FIRE-TUBE BOILERS.

An Account of the Experiments made by Chief Engineers Loring and Baker, U. S. Navy, on a Horizontal Fire-Tube and a Vertical Water-Tube Boiler, at the Washington Navy Yard, to ascertain their relative Economic Vaporizations with different kinds of Coal.

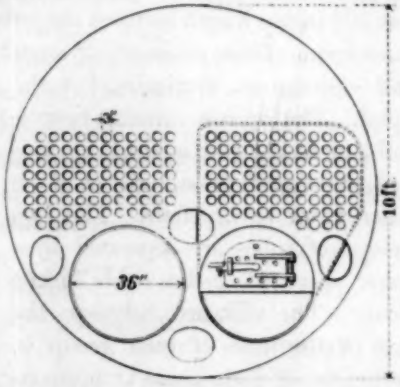
By Chief Engineer ISHERWOOD, U. S. Navy.

(Continued from vol. lvii, page 24.)

THE HORIZONTAL FIRE-TUBE BOILER.

The shell of the horizontal fire-tube boiler is a cylinder with flat ends at right angles to its axis. The front end is also the front tube-plate. This cylinder is ten feet in diameter and nine feet in length, externally. The uptake, which is of sheet iron bolted to the front end of the cylinder, projects beyond this length. The plates of the shell are $\frac{11}{16}$ths of an inch thick, and double riveted. The flat ends of the shell above the tube-boxes are stayed directly across with iron rods $1\frac{1}{8}$ inches in diameter and 10 inches between axes, attached to double angle iron riveted vertically to the ends. All other flat surfaces are stayed with socket-bolts $1\frac{1}{8}$ inch in diameter and 6 inches between centres.

FIG. 3.

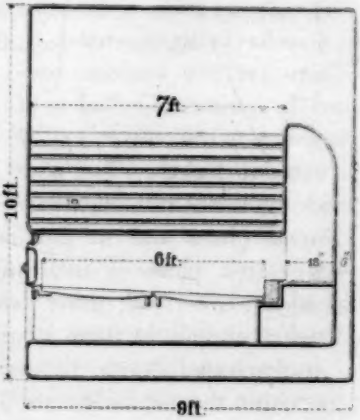


There are two furnaces contained in horizontal cylinders of 3 feet internal diameter and 7 feet extreme length. The axes of these cylinders are in the same horizontal plane and 42 inches apart. The cylinders are composed of iron plates $\frac{1}{2}$ inch thick, butted, and double-riveted to inner welts below the grate bars; they are single riveted to the boiler-shell and are in three lengths, flanged where the lengths meet, and single-riveted thereby through a ring placed between them. The grates within these cylinders are 6 feet in extreme length, composed of cast iron bars in two lengths of 3 feet each. The bridge-wall is of cast iron faced with fire-brick and is 6 inches high above the level of the grates. The top of the grates is 18 inches below the crown of the furnace, at the front, and 21 inches below it at the back.

Each furnace has a separate back connection 18 inches long, lengthwise the boiler, with its top rounded on a quadrantal arc of 14 inches radius. Its back is flat and separated from the back end of the boiler-shell by a flat water-space six inches wide, including thicknesses of metal. The bottom of the connection is a horizontal extension of the bottom of the cylinder containing the furnace and the sides are flat. The inner side is vertical and rises from the horizontal diameter of the furnace. The outer side, at top, is vertical for the depth occupied by the tubes, and thence slopes inwards on a tangent to the cylinder containing the furnace. The cast iron bridge-wall of the furnace is extended clear across the connection so as to occupy the whole of the lower portion.

From each back connection to the uptake proceed 86 horizontal fire-tubes of seamless brass, $\frac{1}{8}$th of an inch thick; 70 of them are expanded on one side and riveted over the other side of their tube-plates, and the remaining 16 act as stays, having nuts upon their outer ends. The boiler thus contains 172 tubes, of three inches outside diameter, and 6 feet $10\frac{3}{8}$ inches length between the tube plates, which are of $\frac{11}{16}$ths inch thick iron. These tubes are arranged in twenty-four rows horizontally and eight rows vertically, but the number in all the rows is not equal. The top row contains twenty-two tubes, the bottom row contains eight tubes, the row next to the bottom, twenty-two tubes, and each of the other rows twenty-four. The two groups of tubes are separated by a water space 11 inches wide in the clear. The distance between the axes of the tubes of each group is, vertically, 4 inches, and, horizontally, $4\frac{1}{16}$ inches.

FIG. 4.



All the tubes discharge into one uptake, which at the top delivers the gases of combustion into a horizontal sheet iron flue connecting the uptake of the horizontal fire-tube boiler with that of the vertical water-tube boiler, and from the centre of this flue, the chimney, common to both boilers, rises. The uptake has the usual doors for access to the

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tubes for sweeping, etc., and the furnace doors were thoroughly perforated for the admission of air above the incandescent fuel on the grates.

The following are the principal dimensions and proportions of the horizontal fire-tube boiler:

Diameter of the shell,	10 ft.
Length of the shell, exclusive of the uptake,	9 ft.
Number of furnaces,	2
Breadth of furnaces,	3 ft.
Length of grates,	6 ft.
Total area of grate surface,	36 sq. ft.
Total number of tubes,	172
External diameter of tubes,	3 in.
Internal diameter of tubes,	$2\frac{1}{8}$ in.
Length of tubes in clear of tube-plates,	$82\frac{3}{8}$ in.
Total cross area for draught above the bridge-walls,	5·55 sq. ft.
Total cross area for draught through the tubes,	7·24 sq. ft.
Cross area of the chimney,	12·57 sq. ft.
Diameter of the chimney,	4 ft.
Height of the chimney above the level of grate-bars,	60 ft.
Heating surface in the two furnaces,	64 sq. ft.
Heating surface in the 172 tubes, measured on their inner circumference,	861·24 sq. ft.
Heating surface in the two back connexions,	76·5 sq. ft.
Heating surface in the one uptake,	17·26 sq. ft.
Total water heating surface in the boiler,	1019 sq. ft.
Square feet of water heating surface per square foot of grate surface,	28·30
Square feet of grate surface per square foot of cross area above bridge-walls,	6·49
Square feet of grate surface per square foot of cross area through the tubes,	4·97
Square feet of grate surface per square foot of cross area of chimney,	2·87
Water room to 6 inches above tubes,	325 cubic ft.
Steam room from 6 inches above tubes,	161 cubic ft.
Greatest height of steam room,	2·35 ft.

MANNER OF MAKING THE EXPERIMENTS.

With the precedingly described boilers six experiments were made, of thirty consecutive hours duration each, and in precisely the same manner. Of these experiments, two were made with the horizontal fire-tube boiler, one being made with Pennsylvania anthracite, and the other with semi-bituminous coal from the Cumberland mines of Maryland. The remaining four experiments were made with the vertical water-tube boiler and, of these, two were made with Pennsylvania anthracite and were nearly repetitional; one was made with semi-bituminous coal from the Cumberland mines, and the last was made with a bituminous caking coal of unknown locality.

The anthracite was of better quality than the average, and the semi-bituminous coal was of poorer quality than the average, in this respect—that the former had a less, and the latter had a greater percentage of refuse than the average. The average proportion of refuse in fair merchantable anthracite is one-sixth, and in fair merchantable semi-bituminous coal, one-eighth. Of course, the quality of the gasifiable portion of these coals is not affected by their percentage of refuse.

The vaporization took place under the atmospheric pressure, increased slightly by the resistance opposed by the escape pipe to the effluent steam.

Although the boilers stood side by side in the boiler house, and delivered their gases of combustion into the same chimney, they were not experimented with simultaneously. The experiments with the horizontal fire-tube boilers were made first, and those with the vertical water-tube boiler last, a partition of brick masonry being temporarily placed in the horizontal flue connecting the uptakes of the boilers, just beyond the chimney, in each case. Of course, by this arrangement the entire chimney, which was of sufficient cross area for both boilers, was used with each. This, and the fact that the experiments were made at different times under different atmospheric conditions, prevented the possibility of ascertaining the maximum rates of combustion for the two boilers. In the experiments as actually made, there were no attempts to force the fires, which were allowed to burn without further attention than what was required to keep them level, clean, free of holes and about ten inches thick.

The experiments were made during the months of March and April,

1873, and the boilers were thoroughly protected by a non-conducting covering of asbestos.

In commencing an experiment, the fires, of 10 inches thickness, were brought to steady action with the steam freely blowing off through the escape pipe, and with the water in the boiler at about 6 inches above the top of the tubes. The fires were then carefully leveled, the height of water in the boiler exactly adjusted, the thickness of the fires noted and the experiment held to commence. Up to this time no account was taken of the coal and water; but, from this time to the expiration of the thirty hours, all the coal thrown into the furnaces was accurately weighed, and all the feed-water admitted to the boiler was accurately measured in a tank, and the quantities noted hourly. At the end of the experiment the fires were thoroughly cleaned and made of the same thickness as at the commencement, with the water level at precisely the same mark.

All the coal and all the refuse from it were weighed on the same scales in the same iron tub, counterbalanced to prevent error. The same firemen were employed throughout.

During the experiments, regular watches were kept by Assistant Engineers of the Navy, who entered in the columns of a tabular log all the necessary observations from hour to hour.

The data and results of the experiments will be found in the following table, in which the headings of the columns and the descriptions of the quantities on the lines are so full that no further explanation is needed. The observed data are from the original notes of Chief Engineer Baker, but the computations were made by the writer.

RESULTS.

In order that the results of the experiments should be strictly comparable, as regards the economic vaporization of water, they should have been made with equal quantities of water vaporized in equal time, which implies equal quantities of the heat produced by the fuel, absorbed by the water in equal time. This condition, however, does not obtain in the experiments as perfectly as could be desired, but the departures from it were not sufficiently wide to materially affect the comparisons, owing to the facts that the rate of combustion at the maximum was moderate, and that the heat-absorbing surface was great in proportion to the quantity of heat thrown upon it per hour.

In the case of the two experiments D and E, made on anthracite with the vertical water-tube boiler, 116,667·233 and 129,955·288 pounds of water were vaporized during the experiments from the temperature of 212 degrees Fahrenheit, on the supposition that the water was supplied at that temperature, and the economic results were respectively 13·0764 and 13·0477 pounds of water vaporized from the temperature of 212 degrees Fahrenheit by one pound of the combustible portion of the anthracite. The difference in the potential vaporization appears here not to have influenced the economic vaporization. It is undoubted, however, that to some extent—more or less, according to circumstances,—increased potential vaporization is accompanied by decreased economic vaporization; but, when the maximum potential vaporization is not great, and the heat-absorbing surface is great in proportion to the quantity of heat absorbed in a given time, the effect of any difference in the potential vaporization on the economic vaporization becomes sufficiently small to be neglected from a practical point of view.

For the comparison of the economic vaporizations by the horizontal fire-tube and the vertical water-tube boilers, *when burning anthracite*, we have experiments A and E, experiment D not being included because of its less potential vaporization. In experiment A, made with the horizontal fire-tube boiler, the economic vaporization from the temperature of 212 degrees Fahrenheit was 11·4717 pounds of water per pound of the combustible portion of the anthracite; while, in experiment E, made with the vertical water-tube boiler, it was 13·0477 pounds of water. Hence, *with anthracite*, the vertical water-tube boiler, under the experimental conditions, vaporized per pound of fuel $\left(\frac{13{\cdot}0477-11{\cdot}4717\times 100}{11{\cdot}4717}\right)=13{\cdot}74$ per centum more water than the horizontal fire-tube boiler. This percentage would have been less had the potential vaporizations in the two experiments been equal.

For the comparison of the economic vaporizations by the horizontal fire-tube and the vertical water-tube boilers, *when burning semi-bituminous coal*, we have experiments B and C, in which the potential vaporizations were nearly equal. In experiment B, made with the horizontal fire-tube boiler, the economic vaporization from the temperature of 212 degrees Fahrenheit was 11·5670 pounds of water per pound of the combustible portion of the semi-bituminous coal, while, in experiment C, made with the vertical water-tube boiler, it was 13·8477

pounds of water. Hence, *with semi-bituminous coal*, the vertical water-tube boiler, under the experimental conditions, vaporized per pound of fuel $\left(\frac{13{\cdot}8477-11{\cdot}5670\times100}{11{\cdot}5670}\right)=19{\cdot}72$ per centum more water than the horizontal fire-tube boiler.

It will be remembered that with equal weights of the combustible portion of *anthracite*, the vertical water-tube boiler was economically somewhat less than 13·74 per centum superior to the horizontal fire-tube boiler, and we now see this superiority increased to 19·72 per centum for equal weights of the combustible portion of *semi-bituminous coal*. To what should this increase be attributed? The distillation of semi-bituminous coal in the furnace, previous to the incandescence of its fixed carbon, produces a very much larger quantity of combustible gases than the similar distillation of anthracite. The fixed carbon of both coals is consumed on the grate in the solid form, but the combustion of the gases takes place after their distillation, in the furnace above the fixed carbon, and in the tubes also, if heat and oxygen enough be present, *and the gases be sufficiently intermingled with the latter*. In the horizontal fire-tube there is nothing to produce this necessary intermingling; there is no obstruction, the gases pass rapidly through it in parallel streaks unmixed; but, with the vertical water-tubes, the tubes themselves are mechanical mixers, standing, as they do, in and across the current of the gases. To their position, therefore, may be attributed the marked difference in the amount of their economic gain when vaporizing water with semi-bituminous coal and when vaporizing it with anthracite—the one a very gas-producing and the other almost a non-gas-producing fuel. The superiority of the vertical water-tubes may be due not only to their better absorption of heat, but to their contributing to its development by their mechanical mixing of the coal-gases and the atmospheric oxygen. If these hypotheses are correct, the vertical water-tube boiler, comparatively with the horizontal fire-tube boiler, should have a greater economic superiority in the vaporization of water the more gas-producing the coal consumed.

It will be observed that the foregoing comparisons between the two boilers are for substantially equal potential vaporizations per hour or, roughly, for equal rates of combustion; but had each boiler been fired to its maximum, about fifty per centum more coal would have been

consumed in the same time in the horizontal fire-tube boiler than in the vertical water-tube boiler, and with about twenty-five per centum less economy per pound of fuel, producing about twenty-five per centum more steam per hour.

As regards the relative economic efficiency of the combustible portion of anthracite and of semi-bituminous coal, *consumed in the horizontal fire-tube boiler*, a comparison of the economic vaporizations per pound of these combustible portions, given in experiments A and B, shows that the two fuels were about equal, the results being, in experiment A, 11·4717 pounds of water vaporized from the temperature of 212 degrees Fahrenheit by one pound of the combustible portion of anthracite, and 11·5670 pounds of water vaporized from the same temperature by the pound of the combustible portion of semi-bituminous coal.

If, however, the comparison be made for the pound of coal in the two cases, assuming the refuse in the anthracite at one-sixth and in semi-bituminous coal at one-eighth of the gross weight, which are the averages in practice, then the economic vaporization of water from the temperature of 212 degrees Fahrenheit per pound of coal becomes $(11{\cdot}4717 \times \frac{5}{6} =) 9{\cdot}5598$ pounds for the anthracite and $(11{\cdot}5670 \times \frac{7}{8} =) 10{\cdot}1213$ pounds for the semi-bituminous coal, or the latter is

$$\left(\frac{10{\cdot}1213 - 9{\cdot}5598 \times 100}{9{\cdot}5598}\right) = 5{\cdot}72$$

per centum superior to the former.

As regards the relative economic efficiency of the combustible portion of anthracite and of semi-bituminous coal, *consumed in the vertical water-tube boiler*, a comparison of the economic vaporizations per pound of these combustible portions, given in experiments E and C, shows that the pound of the combustible portion of the anthracite vaporized in experiment E 13·0477 pounds of water from the temperature of 212 degrees Fahrenheit, while the pound of the combustible portion of the semi-bituminous coal vaporized, in experiment C, 13·8477 pounds of water from the same temperature; hence, the economic efficiency of a pound of the combustible portion of semi-bituminous coal was

$$\left(\frac{13{\cdot}8477 - 13{\cdot}0477 \times 100}{13{\cdot}0477}\right) = 6{\cdot}13$$

per centum greater than that of a pound of the combustible portion of anthracite.

If, however, the comparison be made for the pound of coal in the two cases, assuming, as before, the refuse in anthracite at one-sixth

By Chief Engineer ISHERWO

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE, IN MARCH AND APRIL, 1873, AT THE N
NAVY, ON TWO CYLINDRICAL TUBULAR BOILERS, OF THE SAME DIMENSIONS, BUT DIFFERING IN THE KIND
RETURNED ABOVE THE FURNACES, AND THE OTHER HAVING VERTICAL WATER-TUBES RETURNED ABO
THE ECONOMIC VAPORIZATION UNDER ATMOSPHERIC PRESSURE BY EACH BOILER WHEN BU
THE CUMBERLAND MINES OF MARYLAND, AND A BITUMINOUS COAL OF UNKNOWN

		HORIZON
		Anthracit
	Designation of experiment,	A
BOILERS.	Square feet of grate surface,	36·00
	Square feet of heating surface, calculated for the inner surfaces of the tubes,	1019·00
	Square feet of opening for draught over the bridge-walls,	5·55
	Square feet of opening for draught through the tubes,	7·24
TOTAL QUANTITIES.	Duration of the experiments, in consecutive hours,	30.
	Total number of cubic feet of water vaporized from the temperature of the feed water,	2134.81
	Total number of pounds of water vaporized from the temperature of the feed-water,	133187·0
	Total number of pounds of coal consumed,	15336·0
	Total number of pounds of refuse from the coal in ash, clinker and soot,	1608·0
	Total number of pounds of combustible or gasifiable portion of the coal consumed,	13728·0
	Per centum of the coal in refuse of ash, clinker and soot,	10·48
RATE OF COMBUSTION.	Pounds of coal consumed per hour,	511·20
	Pounds of combustible or gasifiable portion of the coal consumed per hour,	457·60
	Pounds of coal consumed per hour per square foot of grate surface,	14·20
	Pounds of combustible consumed per hour per square foot of grate surface,	12·71
	Pounds of coal consumed per hour per square foot of heating surface,	0·50
	Pounds of combustible consumed per hour per square foot of heating surface,	0·44
TEMPERATURES.	Temperature, in degrees Fahrenheit, of the external atmosphere,	35.
	Temperature, in degrees Fahrenheit, of the gases of combustion in the uptake,	702·
	Temperature, in degrees Fahrenheit, of the feed-water in the tank,	39·
PRESSURE.	Steam pressure in boiler, in pounds per square inch above zero,	17·00
VAPORIZATION.	Total number of pounds of water that would have been vaporized had the feed-water been supplied at the temperature of 100 degrees Fahrenheit, and vaporized under the pressure of 29·92 inches of mercury,	141008·67
	Total number of pounds of water that would have been vaporized had the feed-water been supplied at the temperature of 212 degrees Fahrenheit and vaporized under the pressure of 29·92 inches of mercury,	157484·21
	Pounds of water vaporized from 100 degrees Fahrenheit by one pound of coal,	9·19
	Pounds of water vaporized from 100 degrees Fahrenheit by one pound of combustible,	10·27
	Pounds of water vaporized from 212 degrees Fahrenheit by one pound of coal,	10·26
	Pounds of water vaporized from 212 degrees Fahrenheit by one pound of combustible,	11·47

WATER-TUBE AND FIRE-TUBE BOILERS.

IEF ENGINEER ISHERWOOD, U. S. NAVY.

N MARCH AND APRIL, 1873, AT THE WASHINGTON NAVY-YARD, BY CHIEF ENGINEERS LOI
NSIONS, BUT DIFFERING IN THE KIND AND ARRANGEMENT OF TUBES, ONE HAVING THE ORDI
ERTICAL WATER-TUBES RETURNED ABOVE THE FURNACES. THE OBJECT OF THE EXPERIMENT
PRESSURE BY EACH BOILER WHEN BURNING PENNSYLVANIA ANTHRACITE, A SEMI-BITUMINOU
ND A BITUMINOUS COAL OF UNKNOWN LOCALITY, UNDER THE EXPERIMENTAL CONDITIONS.

	HORIZONTAL FIRE-TUBE BOILER.		VERTICAL WA	
	Anthracite.	Semi-bituminous coal.	Semi-bituminous coal.	An
. . . . .	A	B	C	D
. . . . .	36·00	36·00	36·00	36·00
s of the tubes, . .	1019·00	1019·00	1104·00	1104·00
. . . . .	5·55	5·55	5·55	5·55
. . . . .	7·24	7·24	5·55	5·55
. . . . .	30.	30·	30·	30·
erature of the feed water,	2134.816	2061·670	2008·466	1532·830
ture of the feed-water, .	133187·0	128623·6	125304·3	98749·7
. . . . .	15336·0	15168·0	12979·0	10506·0
r and soot, . .	1608·0	2022·0	2284·0	1584·0
f the coal consumed,	13728·0	13146·0	10695·0	8922·0
. . . . .	10·485	13·331	17·598	15·077
. . . . .	511·200	505·600	432·633	350·200
med per hour, . .	457·600	438·200	356·500	297·400
rface, . . .	14·200	14·044	12·018	9·728
grate surface, . .	12·711	12·172	9·903	8·261
surface, . .	0·502	0·496	0·392	0·317
heating surface, . .	0·449	0·430	0·323	0·269
ere, . . .	35.	43.	43·	30·
ion in the uptake, .	702·	—·	—·	338·
tank, . . .	39·	39·	39·	39·
o, ...	17·00	16·75	16·50	16·00
rized had the feed-water eit, and vaporized under	141008·672	136151·660	132607·757	104461·845
. . . . .				
rized had the feed-water eit and vaporized under	157484·215	152059·706	148101·731	116667·283
. . . . .				
ne pound of coal, . .	9·1946	8·9762	10·2171	9·9431
ne pound of combustible,	10·2716	10·3569	12·3990	11·7083
ne pound of coal, . .	10·2689	10·0250	11·4109	11·1048
ne pound of combustible,	11·4717	11·5670	13·8477	13·0764

INEERS LORING AND BAKER, UNITED STATES

O THE ORDINARY HORIZONTAL FIRE-TUBE

EXPERIMENTS WAS TO ASCERTAIN

I-BITUMINOUS COAL FROM

DITIONS.

TICAL WATER-TUBE BOILER.

	Anthracite.		Bituminous coal.
	D	E	F
	36·00	36·00	36·00
	1104·00	1104·00	1104·00
	5·55	5·55	5·55
	5·55	5·55	5·55
	30·	30·	30·
	1532·830	1769·107	1888·815
	98749·7	110367·4	117835·5
	10506·0	11280·0	13317·0
	1584·0	1320·0	1570·0
	8922·0	9960·0	11747·0
	15·077	11·704	11·789
	350·200	376·000	443·900
	297·400	332·000	391·567
	9·728	10·444	12·331
	8·261	9·222	10·877
	0·317	0·341	0·402
	0·269	0·301	0·335
	30·	47·	56·
	338·	338·	358·
	39·	43·	43·
	16·00	16·18	16·25
	104461·845	116359·742	123869·721
	116667·233	129955·288	138342·737
	9·9431	10·3156	9·3016
	11·7083	11·6827	1054·48
	11·1048	11·5204	10·3884
	13·0764	13·0477	11·7769

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13·8477 p
economic

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If, howe
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ING AND BAKER, UNITED STATES
ARY HORIZONTAL FIRE-TUBE
WAS TO ASCERTAIN
COAL FROM

ER-TUBE BOILER.

racite.	Bituminous coal.
E	**F**
36·00	36·00
1104·00	1104·00
5·55	5·55
5·55	5·55
30·	30·
1769·107	1888·815
110367·4	117835·5
11280·0	13317·0
1320·0	1570·0
9960·0	11747·0
11·704	11·789
376·000	443·900
332·000	391·567
10·444	12·331
9·222	10·877
0·341	0·402
0·301	0·335
47·	56·
338·	358·
43·	43·
16·18	16·25
116359·742	123869·721
129955·288	138342·737
10·3156	9·3016
11·6827	1054·48
11·5204	10·3884
13·0477	11·7769

and in semi-bituminous coal at one-eighth of the gross weight, then the economic vaporization of water from the temperature of 212 degrees Fahrenheit per pound of coal becomes ($13{\cdot}0477 \times \frac{5}{6} =$)$10{\cdot}8731$ pounds for the anthracite and ($13{\cdot}8477 \times \frac{7}{8} =$)$12{\cdot}1167$ pounds for the semi-bituminous coal, or the latter is $\left(\frac{12{\cdot}1167 - 10{\cdot}8731 \times 100}{10{\cdot}8731}\right) =$ $11{\cdot}44$ per centum superior to the former.

To determine the economic efficiency of the combustible portion of the caking bituminous coal relatively with that of the combustible portion of anthracite and of semi-bituminous coal, the economic vaporization of water from the temperature of 212 degrees Fahrenheit, given in experiment F, by the pound of the combustible portion of the caking bituminons coal, will be compared with that given in experiment E by the pound of the combustible portion of anthracite and with that given in experiment C by the pound of the combustible portion of semi-bituminous coal, all three of the experiments having been made with the vertical water-tube boiler.

In experiment E, the pound of the combustible portion of the caking bituminous coal vaporized from the temperature of 212 degrees Fahrenheit $11{\cdot}7769$ pounds of water. In experiment E, the pound of the combustible portion of anthracite vaporized from the same temperature $13{\cdot}0477$ pounds of water. And, in experiment C, the pound of the combustible portion of semi-bituminous coal vaporized from the same temperature $13{\cdot}8477$ pounds of water. Hence, the economic vaporation by the pound of the combustible portion of caking bituminous coal was $\left(\frac{13{\cdot}0477 - 11{\cdot}7769 \times 100}{13{\cdot}0477}\right) = 9{\cdot}74$ per centum less than by the pound of the combustible portion of the anthracite. And the economic vaporization by the pound of the combustible portion of caking bituminous coal was $\left(\frac{13{\cdot}8477 - 11{\cdot}7769 \times 100}{13{\cdot}8477}\right) = 14{\cdot}95$ per centum less than by the pound of the combustible portion of semi-bituminous coal.

Radiometer Pressure.—In some recent experiments, Crookes has employed the torsion balance in order to estimate the molecular pressure within the radiometer. He finds that it varies between 7 ten-millionths and 9 four-millionths of an atmosphere.—*Comptes Rendus.*

CIRCUMSTANCES INFLUENCING THE EFFICIENCY OF DYNAMO-ELECTRIC MACHINES.

By Profs. Edwin J. Houston and Elihu Thomson.*

During the recent competitive trials made at the Franklin Institute as to the relative efficiency of some different forms of Dynamo-Electric Machines, the authors having been entrusted with the work of determining the relations between the mechanical power consumed and the electric and thermic effects produced, took the opportunity thus afforded to make a careful study of many interesting circumstances which influence the efficiency of these machines.

It is purposed in the present paper to select from the many circumstances thus noticed, a few of the more interesting, reserving the others for future consideration.

It will readily be understood that from the comparatively new field in which we have been working, no reliable data of the electrical work of these machines having before been obtained, difficulties constantly arose owing to necessary conditions of operation, and new developments as to the behavior of the machines under varied conditions, were constantly met.

A convenient arrangement of the particular circumstances we are about to discuss may be, 1st, Those affecting the internal work of the machine; 2d, Those affecting the external work, and 3d, The relations between the internal and external work.

The mechanical energy employed to give motion to a Dynamo-Electric Machine is expended in two ways, viz., 1st, In overcoming friction and the resistance of the air; and, 2d, In moving the armature of the machine through the magnetic field, the latter of course constituting solely the energy available for producing electrical current. The greatest amount of power expended in the first way was noticed to be about 17 per cent. of the total power employed. This expenditure was clearly traceable to the high speed required by the machine. The speed therefore required to properly operate a machine is an important factor in ascertaining its efficiency.

The above percentage of loss may not appear great, but when it

* *Read before the American Philosophical Society, Nov.* 1, 1878.

is compared with the total work done in the arc, as heat, constituting as it did in this particular instance over 50 per cent. of the latter, and about 33 per cent. of the total work of the circuit, its influence is not to be disregarded. In another instance the work consumed as friction was equal to about 80 per cent. of that appearing in the arc as heat, while in the Gramme machine experimented with, this percentage fell to 20 per cent. of that which appeared in the arc as heat, and was only about 7 per cent. of the total power consumed in driving the machine.

In regard to the second way in which mechanical energy is consumed, viz.: in overcoming the resistance necessary to move the armature through the magnetic field, or in other words, to produce electrical current, it must not be supposed that all this electrical work appears in the circuit of the machine, since a considerable portion is expended in producing what we term the local action of the machine, that is local circuits in the conducting masses of metal, other than the wire, composing the machine.

The following instances of the relation between the actual work of the circuit, and that expended in local action, will show that this latter is in no wise to be neglected. In one instance an amount of power somewhat more than double the total work of the circuit was thus expended. In this instance also it constituted more than five times the total amount of power utilized in the arc for the production of light. In another instance it constituted less than one-third the total work of the circuit, and somewhat more than one-half the work in the arc.

Of course work expended in local action is simply thrown away, since it adds only to the heating of the machine. And since the latter increases its electrical resistance, it is doubly injurious.

The local action of dynamo-electric machines is analogous to the local action of a battery, and is equally injurious in its effects upon the available current.

Again, in regard to the internal work of a machine, since all this is eventually reduced to heat in the machine, the temperature during running must continually rise until the loss by radiation and convection into the surrounding air, equal the production, and thus the machine will acquire a constant temperature. This temperature, however, will differ in different machines according to their construction, and to the power expended in producing the internal work, being, of

course, higher when the power expended in producing the internal work is proportionally high.

If therefore a machine during running acquires a high temperature when a proper external resistance is employed, its efficiency will be low. But it should not be supposed that because a machine when run without external resistance, that is on short circuit, heats rapidly, that inefficiency is shown thereby. On the contrary, should a machine remain comparatively cool when a proper external resistance is employed, and heat greatly, when put on short circuit, these conditions should be regarded as a proof of its efficiency.

As a rule the internal resistance of Dynamo-Electric Machines is so low that to replace them by a battery, the latter, to possess an equal internal resistance, would have to be made of very large dimensions, so that the efficiency of Dynamo-Electric Machines cannot be stated in terms of battery cells as ordinarily constructed.

In regard to the second division, viz., the external work of the machine, this may be applied in the production of light, heat, electrolysis, magnetism, etc.

Where it is desired to produce light, the external resistance is generally that of an arc formed between two carbon electrodes; the resistance of the arc is therefore an important factor in determining the efficiency. To realize the greatest economy, the resistance of the arc should be low, but nevertheless should constitute the greater part of the entire circuit resistance.

In some of our measurements the resistance of the arc was surprisingly low, being in one instance ·54 ohm., and in another ·79 ohm. It was however in some instances as high as 3·18 ohms.

It may be noted, as an interesting fact, that where the greatest current was flowing, the resistance of the arc thereby produced was low. This is undoubtedly due to higher temperature and increased vaporization from the carbons. In this latter case also the greatest amount of light was produced.

The amount of work appearing in the arc as measured by the number of foot pounds equivalent thereto, is not necessarily an index of the lighting power. In two instances of measurement, the amount of energy thus appearing in the arc was equal, while the lighting powers were proportionately as three to four. This apparent anomaly is explained by considering the resistance of the arc, it being much

less in the case in which the greater light was produced. The heat in this case being evolved in less space, the temperature of the carbons and therefore their light-giving powers, was considerably increased.

A few remarks on the economical production of light from electrical current may not be out of place. The light emitted by an incandescent solid will increase as its temperature is increased. In the voltaic arc the limit to increase of temperature is in the too rapid vaporization of the carbon. Before this point is reached, however, the temperature is such that the light emitted is exceedingly intense. No reliable method of measuring the temperature of the arc has as yet been found.

A well known method of obtaining light from electrical currents is by constructing a resistance of some material such as platinum having a high fusing point and heated to incandescence by the passage of a current. When platinum is employed the limit to its increase of temperature is the fusing point of the platinum, which is unquestionably but a fraction of the temperature required to vaporize carbon. Were the falling off in the amount of light emitted merely proportional to the decrease in temperature, the method last described might be economical. Unfortunately however for this method, many facts show that the decrease in the light emitted is far greater than the decrease of the temperature. Most solids may be heated to 1000°F., without practically emitting light. At 2000°F., the light emitted is such that the body is said to be a bright red. At 4000°F., the amount of light will have increased more than twice, probably as much as four times that emitted at 2000°F. It is reasonable to suppose that with a further increase of temperature, the same ratio of increase will be observed, the proportionate increase in luminous intensity far exceeding the increase in temperature.

It would therefore appear that the employment of a resistance of platinum or other similar substance, whose temperature of alteration of state as compared with that of carbon is low, must be far less economical than the employment of the arc itself, which as now produced has been estimated as about two or three times less expensive than gas.

Indeed it would seem that future improvements in obtaining light from electrical currents will rather be by the use of a sufficient resist-

ance in the most limited space practicable, thereby obtaining in such space the highest possible temperature.

Perhaps the highest estimate that can be given of the efficiency of Dynamo-Electric-Machines as ordinarily used, is not over 50 per cent., our measurements have not given more than 38 per cent. Future improvements may increase this proportion. Since the efficiency of an ordinary steam engine and boiler in utilizing the heat of the fuel is probably overestimated at 20 per cent., the apparent maximum percentage of heat that could be recovered from the current developed in a Dynamo-Electric-Machine would be overestimated at 10 per cent. The economical heating of buildings by means of electricity may therefore be regarded as totally impracticable.

Attention has, long ago, been directed to the use of Dynamo-Electric Machines for the conveyance of power. Their employment for this purpose would indeed seem to be quite promising. Since in this case one machine is employed to produce electrical currents, to be reconverted into mechanical force by another machine, the question of economy rests in the perfection of the machines and in their relative resistances.

In respect to the relations that should exist between the external and internal work of Dynamo-Electric Machines, it will be found that the greatest efficiency will, of course, exist where the external work is much greater than the internal work, and this will be proportionately greater as the external resistance is greater. Our measurements gave in one instance the relation of ·82 ohm. of the arc to ·49 ohm. of the machine, a condition which indicates economy in working. The other extreme was found in an instance where the resistance of the arc was 1·93 ohm., while that of the machine was 4·60 ohms., a condition indicating wastefulness of power.

Nickel Compass Needles.—Joseph Wharton has sent to the French Academy a marine compass with a nickel needle, constructed nearly after Sir Wm. Thomson's model. Four similar compasses have been placed on Russian cruisers. It is proposed that the fifth should be put on a French ship for comparison with steel needles.—*Comptes Rendus.*

PHOTOGRAPHY AS APPLIED TO THE REPRODUCTION OF PLANS AND DRAWINGS.

By David Townsend, B. S.

The various means by which drawings may be copied without the aid of a camera will, I think, be of interest to all, but more especially to draughtsmen and engineers whose time is valuable and whose dislike to making intricate tracings, proverbial. The different processes, which I will describe in detail, were all practiced in my laboratory with a view to the adoption of the best by the works with which I am connected. I write, therefore, to benefit those who may be already on the road or who wish to follow after. But, before passing to details, it would be well to consider the substances used as sensitizers, or picture producers, and the effect which light has upon them. This will enable us to better understand the chemistry of the processes and perhaps point the way to new fields and improvements. The compounds most used to make a sensitive paper are chloride of silver, the persalts of iron and uranium, and bi-chromate of potassium. These will be considered, with regard to the changes produced on them by light, in the order named.

Chloride of Silver.

Chloride of silver was the first substance noticed that changed by exposure to light. Its properties were known to the alchemists of the sixteenth century, who called it "*lua cornua*," but it was first brought to notice by the researches of Scheele in 1778. This celebrated chemist observed that whenever chloride of silver was exposed to light, chlorine was liberated, producing a blackening, and that on treating this black residue with ammonia, metallic silver was left behind. The present theory is that the chloride is reduced to the state of sub-chloride by the action of light and free chlorine is liberated. It was also observed that when silver chloride was exposed in the presence of nitrate of silver the blackening was much more rapid, owing to the fact that the free chlorine liberated united with the silver nitrate to produce fresh silver chloride. Thus we conclude that the sensitiveness is increased in proportion as there is a chlorine absorbent present. If,

then, we sensitize a piece of paper, that has previously been salted, with nitrate of silver in solution, the sodium chloride will precipitate some of the silver as chloride while the excess will still remain as nitrate, thus making a highly sensitive surface and fulfilling all that is required for printing pictures.

Iron and Uranium.

The next salts we shall consider, in regard to their behavior when exposed to light, are those of iron and uranium. Their reactions are similar, and we are indebted to Sir John Herschel and Niepce de St. Victor for the discovery of their peculiar properties. If we take two pieces of paper and brush them with a solution of ferric chloride, then expose one to the light and retain the other, finally flow ferricyanide of potassium over both we will find that the one that was exposed will turn blue, while the other will remain unaltered. Now, as ferricyanide of potassium precipitates iron only in the *ferrous* state, we conclude that the action of light has been to reduce the ferric chloride (Fe_2Cl_6) to ferrous chloride ($FeCl_2$). By similar experiments we may say that the action of light on all ferric salts, under certain conditions, is to reduce them to the ferrous state. The conditions to which I refer are the presence of some organic matter, such as the paper, glazing, etc., because otherwise the reduction is exceedingly slow. This property of reduction by light possessed by all per-salts of iron should be especially remembered, as it forms the basis of a number of processes whose details will be given hereafter. The action of light on the per-salts of uranium, especially the nitrate, is exactly similar to its action on iron, it reduces all uranic to uranous compounds.

Chromium.

The remaining metallic compounds which are of value as sensitizing agents are those of chromium combined with the alkalies. The alkaline bichromates, and especially of potassium are, under certain conditions, far more sensitive to the action of light than either nitrate or chloride of silver. Potassium bi-chromate ($K_2Cr_2O_7$) by itself is a permanent salt, but when in contact with organic substances, it quickly decomposes in the light. This property and its extreme sensitiveness renders it invaluable to photography, in which it forms the basis for numerous processes, such as the Carbon, Woodbury, Photolithographic,

etc. It is also the principal ingredient in the aniline process, at present much used in Europe for the reproduction of drawings.

Having thus seen the action which light produces on the different substances, we will now consider how we can best use their peculiar properties for producing photographic pictures. It would be well to mention here that in *all* cases, whatever the process, the operations of producing a picture are substantially the same. First, there must be a suitable support, or ground on which the picture is to be produced, such as paper; second, the ground must be coated with substances, called sensitizers, which shall be sensitively affected by the light; third, chemical reagents must be used which will combine with and develop the image produced upon the sensitive paper, and, fourth, fixing agents or chemical solvents must be used that will dissolve all unaltered sensitizing agents and make the picture permanent. Let us now consider the different processes.

Silver Process.

As was stated before, Scheele was the first to point out the effect which light had on chloride of silver, but Sir Humphry Davy, in 1802, was the first to produce a picture by the silver process; since that time it has made rapid strides toward perfection and it is to-day the only printing process that has taken firm hold on practice. Of all the processes which I shall give, it is the most reliable, the easiest to govern, and yields the best results. The manipulations required are more numerous than difficult, and after a little practice, become as easy as simpler methods. The operations taken in their order are as follows:—

1. Preparing the paper, or salting.
2. Sensitizing.
3. Exposing.
4. Washing.
5. Toning.
6. Washing.
7. Fixing.
8. Final washing.

(1) *Salting the Paper.*

As the plain salted paper, which is invariably used for this process, is easily obtainable in the markets in sheets of any size, it is not necessary that time should be consumed in its preparation; but for those who are not convenient to any depot, or who wish to prepare it

for themselves, the following directions will be of value. The papers most preferred are the Rive and Steinbach, but other brands of English and American manufacture will answer just as well for this purpose. If the paper be of the finest quality imported the salting solution is composed of

Ammonium chloride,	1 part.
Pure water,	46 "

but if it be the ordinary market article, or has not sufficient sizing, the solution should contain:

Sodium chloride,	4 parts.
Ammonium chloride,	6 "
Sodic citrate,	10 "
Gelatine,	1 "
Pure water,	460 "

Sufficient of the solution must be made to cover the bottom of a pan to the depth of half an inch. The pan should be two inches larger each way than the sheet to be salted and may be made of wood or tin, properly protected. It would be well to state here that all the pans, with the exception of the silver bath, can be made of tin thickly coated on both sides with asphalt, which renders them impervious to acids and alkalies. These pans should be made of a size to suit the largest drawing to be copied, and each operation should have a pan especially for that purpose. The salting bath is now poured into a pan, and all bubbles removed from the surface with a piece of paper, the paper to be salted is then taken between the thumb and first finger of each hand, at opposite corners, and curved so that on letting it down until in contact with the liquid, the centre line will touch first. The right hand is lowered carefully, and then the left, until the paper floats evenly upon the surface of the solution. If any air bubbles are observed under the sheet, one corner is lifted and the bubbles touched with a glass rod. This is very important, otherwise the air, acting as a cushion, prevents the salting solution from touching the paper and leaves a spot which will not become sensitive in the next operation. After allowing to float three or four minutes, the paper is raised by lifting two corners on the short side and drawing it evenly from the bath, after which it is suspended from a line by compression pins and allowed to dry. The process of swimming the paper, as

described above, is also applied when sensitizing, and should be practiced until perfection is attained. Care must be exercised in both operations not to allow the solution to flow on the back of the paper, as a black spot will be the result when it is exposed to the light. When the paper is dry, it is taken from the line, stamped or marked on the *back*, and laid away flat, to be used as needed. A description of the preparation of albumen paper is not necessary, as it is seldom used for reproductions and can be bought much cheaper than one could make it. For copying very fine engravings or architectural designs, it is sometimes desirable because of the brilliant finish and the pleasant color when toned.

(2) *Sensitizing.*

We now come to the second operation, namely, sensitizing, or applying a substance which will be affected by the light. In this case, we use nitrate of silver, the theory being that when the salt in the paper comes in contact with a solution containing the nitrate, chloride of silver is precipitated, which forms an exceedingly sensitive surface, in the presence of an excess of nitrate of silver and organic matter.

The silver bath consists of:—

Cryst. silver nitrate,	1 part.
Citric acid,	½ "
Alcohol,	1 "
Distilled water,	10 "

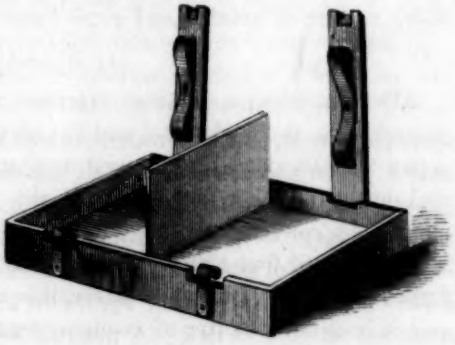
The pure crystallized nitrate of silver is dissolved in one portion of the water, the citric acid in another, and the solutions added, together with the alcohol. Paper sensitized with this bath will keep unaltered for months, whereas, if only nitrate of silver and water had been used, it would turn yellow in a short time. Enough of the bath should be made up to float the paper without touching the bottom of the pan. The vessel in which the sensitizing is performed consists of a tin pan, thickly painted with asphalt, which, when dry, is coated by means of a brush with melted wax. This, when cold, forms a good lining which is not in the least affected by the silver and which does not affect or contaminate it. I have used such a pan for months without any perceptible change in either the pan or bath. This forms a cheap and desirable substitute for porcelain, which would be difficult to get sufficiently large. The manipulation of the paper is the same as

described under the head of salting, being shortly as follows:—The paper is taken at two opposite corners and bent evenly without making any creases or breaks. It is then held over the bath and lowered gently until it touches the liquid. One corner is then lowered until half the paper lies on the bath, then the other is treated likewise The paper should always be rolled with the salted side out, otherwise the edges will dip into the bath on floating it, and cause spots on the back. When the paper is very large it is necessary to have an assistant to prepare it properly. If any bubbles appear under the paper, they must be carefully removed with a glass rod, but when the sheets are large it will be more convenient to touch the spots with a clean brush moistened with the solution, on taking the paper off the bath. The paper is allowed to float for one minute in winter and forty to forty-five seconds in summer. The temperature of the bath is also important, because if it be ice-cold sensitizing will proceed very slowly, therefore it is best to warm the liquid slightly in very cold weather. The paper is just the opposite, as it keeps best when cold. Sensitizing should be performed in a dark room, photographically speaking; that is, in a room lighted only by such colors as have no actinic action on sensitive substances, such as red, orange, or yellow. My own laboratory is arranged with heavy yellow shades, put on rollers which slide in grooves, thus I can have actinic or non-actinic light at pleasure by simply raising or lowering the shades. It would be well to have such an arrangement, as all the operations to the final washing require to be performed in non-actinic light. Care should be taken not to let the silver solution wet the back of the paper, and to avoid touching it with unclean fingers, as black spots will appear when the sheet is exposed, and mar the beauty of the drawing. When the paper is sufficiently sensitized, it is drawn carefully from the bath, and suspended from a line by compression pins, to dry. A piece of blotting paper should be placed under it to catch the silver solution which drops off and which may be regained. The silver bath should be occasionally tested for strength, and, if weak, the proper amount of new nitrate added. It may also become cloudy, due to organic matter, but this may be removed by adding a few drops of potassium permanganate in water (1 to 100) or until a faint pink color is produced, then putting it in the sunlight for several hours. Silver stains on the hands may be removed by rubbing

them with cyanide of potassium and water, but as this salt is a deadly poison it should be used with great care.

(3) *Exposing.*

Next is the exposing of the prepared sensitive paper to the action of light, under a drawing in order to produce a copy. The theory of the operation has been explained; it is carried out in what is known as the printing frame (Fig. 1). This consists of a wooden box having four shallow sides, two to four inches in height, the front being a piece of plate glass, fitting in the frame, and the back (C) consisting of two pieces provided with hinges so that either side may be opened without disturbing the other. The back is pressed tightly against the glass by means of a couple of springs (A and B) fastened on two cross pieces of wood held by catches and hinges to the frame. To the back is glued a soft piece of canton flannel which presses against the glass. These frames may be procured ready made from 3 × 4 inches up to 20 × 24 inches, and other sizes may be had to order. The frame is carried into the dark room, the back removed, and the drawing, if on tracing paper, is put in with its right side against the glass; the sheet of prepared paper is then placed with its sensitive side against the back of the drawing; two or three thicknesses of canton flannel are next laid in and then, after making all as smooth as possible, the back is replaced and the springs shut. If, on turning it over, any wrinkles appear, that side of the frame is re-opened and a piece of paper put against the spot, when all will come smooth on again closing the frame. The frame is now carried into the light and left until the paper turns brown, which it will do in a short time. It is then carried back and opened or, if not in sunlight, it may be quickly examined without taking it to the dark room. If all the lines are still white, it must be closed and again exposed to light, but if the white lines are slightly brown, the exposure is sufficient. In every case the print should be over exposed, as it fades considerably in the subsequent operations.



No special directions need be given in regard to time, as it varies considerably and is, besides, easily controlled. The picture produced will be a positive, or like the original, except it will have white lines on a dark ground. In order to produce dark lines on a white ground, two prints are required to be made, one reversed, which is finished and then used as a negative to produce the desired positive. Drawings made on tracing cloth may be printed either as positive or negative at will, but where the original is on regular drawing paper, a negative only can be produced, owing to the thickness of the paper. Originals made on paper that is soiled, or yellow from age, can not be copied because the color makes them non-actinic. It would be well to remember that the more opaque the lines of the original, the better will be the copy, therefore we make use of the non-actinic properties of certain colors and mix brown, vermillion, or yellow with the India ink used in making the drawing. It is a good plan in large establishments, where a great many copies of one drawing are required, to pencil the original on paper and finish only the tracing which may be kept as a negative to reproduce any number of copies. My own experience has been that tracing cloth is much better than paper, as it is less liable to tear or wrinkle and gives more accurate results.

(4) *Washing.*

After obtaining a sufficient exposure, as directed above, the frame is brought into the dark room and the picture removed; it is then put in a pan of sufficient size, arranged so that water may run in at one side and out at the other, and left until the water becomes clear. If this cannot be conveniently accomplished, it is placed in a pan and the water changed four times. Now, as all the parts protected from the light still contain nitrate of silver, this will be dissolved in the water and it becomes a matter of economy to recover it. When the print is small, the water may be preserved in a keg and the silver extracted at leisure, but where running water is used, other means must be resorted to. The easiest way is to place two old felt hats, each containing a handful of common salt, under the exit pipe, when the silver in passing through the salt will be precipitated as chloride and caught in the fibers of the felt. In the course of time the hats will become saturated and may then be dried, burned, and the silver extracted. The next two operations, viz., (5) Toning and (6) Washing, are seldom performed for copying drawings, but the print is immediately fixed after being

washed. For very fine line engravings, or for copying photographs, they are important, and so I will describe them.

(5) *Toning.*

By toning we mean giving color or tone to the picture. The chemical theory is somewhat complicated but depends principally upon the fact that when a neutral solution of some metallic chloride, such as gold or platinum, comes in contact with the washed print the chlorine leaves the gold and combines with the silver, thus forming a deposit of gold on the picture. The chloride of gold is generally used for this purpose and a normal solution is made by dissolving

Chloride of gold and sodium,	1 part.
In dist. water,	50 "

This is kept in a bottle and for every sheet of 20 × 24 inches 3 cc. are taken and mixed with 300 cc. of the following solution:—

Borax,	1 part.
Water,	150 "

It is sometimes convenient to keep a toning bath made up which can be used a number of times; in this case it should consist of:—

Chloride of gold,	1 part.
Chloride of calcium,	1·4 "
Water,	4,564 "

A little gold should be added from time to time, as the bath becomes exhausted. As nothing but small prints will require toning, a suitable porcelain dish should be provided and kept solely for this purpose.

(6) *Washing.*

This washing is merely to remove surplus toning solution and is not very important. Five minutes in running water will be sufficient, and the waste need not be saved as it is too dilute to pay for the trouble of extracting the silver.

(7) *Fixing.*

After removing all metallic salts, soluble in water, by washing, it is next necessary to dissolve out those still insoluble and remaining in the parts unacted upon, so that when the picture is finished and brought into the light,no change will take place. The solvent generally used is hyposulphite of sodium, or "hypo" solution, as it is technically termed.

This salt has a peculiarity which should be remembered, namely, when in excess it acts as a solvent for salts of silver, but when the latter are in excess, the silver is precipitated as sulphide which, when in contact with the paper, becomes black and insoluble. Great care must therefore be taken to have the hands perfectly free from "hypo," when silvering the paper or in afterwards handling it, otherwise black spots and finger marks will be produced. The fixing bath consists of:—

a.	Hyposulphite of soda ($Na_2S_2O_3$),	1 part.
	Water,	10 "
	Concentrated ammonia,	$\frac{1}{6}$ "
	or	
b.	Saturated solution of hyposulphite,	1 part.
	Water,	8 "
	Saturated solution bicarbonate of soda,	$\frac{1}{4}$ "

The alkali in both cases is used to neutralize any free acid in the solution which would otherwise liberate sulphur and produce black spots on the print. I think formula (*b*) is preferable to formula (*a*), because the ammonium in the latter causes the paper to become very tender and it is much more easily torn. The solution is put in a pan kept especially for the purpose, and the washed print transferred by taking two corners and lifting it carefully from the surface of the water. It is then let down as quickly as possible and speedily covered on all parts with the fixing solution, being careful to remove all bubbles. It is allowed to remain completely immersed for eight to ten minutes in warm weather, but if the bath is cold, a much longer time will be required. When the paper looks transparent the fixing is finished. The prints fade considerably in this bath, but regain some of their color when washed and dried. The fixing solution must now be removed from the paper or it will dissolve the image, and this is accomplished by the last operation to which the paper is subjected, namely—

(8) *Final Washing.*

The print, which is now very tender, is taken by the two shortest corners and raised off the fixing bath; it is allowed to drain thus for a short time, and is then carried to a pan kept especially for this purpose. The thoroughness with which this washing is performed will determine the durability of the picture. The prints cannot be washed too long, it being customary in photographic establishments to leave them in

water all night; but for drawings, if the water be *completely* changed eight or ten times, it will suffice. In any case, let them be washed as long as the time will allow. The print is then removed and pressed between blotting papers, which absorb all the surface moisture and make the print much lighter. It is now carried into a light room, free from dust, suspended from a line by spring clips, and left until dry. Care must be taken not to tear the paper, and thus spoil the work. When dry, the print is removed and trimmed, and is considered finished. The pieces of paper and trimmings should be preserved, as they contain silver, which may be extracted, or sold to dealers, who give nitrate of silver in return.

I have described this process at some length, believing it the best that can be adopted. It has numerous advantages, which will recommend themselves to all having much copying work to do. It is true, first cost is against it, but the results, especially for large work, are the best that can be obtained from any of the processes. We will now pass on to other methods.

Iron.

Next in importance to the salts of silver, come those of iron, and their reactions furnish us with numerous methods for reproducing drawings. The compounds of iron most used are certain double salts, such as citrate of iron and ammonia, oxalate of iron and potassium, tartrate of iron and ammonium, and, of the single salts, the oxalate and per-chloride. In every case the iron must be in the ferric state, otherwise no reduction will occur, and consequently no picture will be produced. All the processes depend upon the reactions of ferro- and ferri-cyanide of potassium on the salts of iron, as already explained. The only thing we have to consider, then, in choosing a salt for a sensitizer is, which one will be the most sensitive to light, and can be procured cheapest. There are two processes which may be considered as typical, the first being called

Pellet's Process.

This was invented by H. Pellet, of Paris, and is quite recent. It gives a blue picture on a white ground, the operations being as follows:

The best quality of paper must be used, or the per-chloride of iron which is used to sensitize it will soak through, making very ugly spots on the back when developed. If the paper is not sufficiently glazed, liquid gum or gelatine should be added to the sensitizing bath. I obtained the best results in my experiments by using albumenized paper

such as is used in portrait photography. The paper is cut to suit the drawing, which for this process must be on tracing cloth, and is then sensitized by floating it, as before described, on a bath composed of

Per-chloride of iron, ...	10 parts.
Water, ...	100 "
Citric or tartaric acid, ...	5 "

The sensitizing must be performed in a dark room and the solution always excluded from the light. The paper is allowed to remain on the bath for thirty seconds, when it is carefully removed and hung in a warm place to dry. It can then be used immediately or preserved unchanged in a dark place. The tracing to be copied is placed in a printing frame together with a sensitive sheet of paper, and is then taken into the light. In sunlight, from fifteen to forty seconds will be sufficient to reduce all the iron to the state of proto-chloride, except such parts as are protected by the black lines which will still remain in the ferric state. If the day be cloudy, from fifteen to twenty minutes will be necessary to complete the reduction. The time of exposure can be determined by a few experiments, as it will vary considerably with the time of the year, the light being twice as strong in summer as in winter. When the exposure is complete, the frame is brought back into the dark room and opened, when a faint image will be observed on a deep orange-yellow ground. The paper is now plunged into a bath containing

Yellow prussiate of potash (K_4FeCy_6), . .	24 parts.
Water, ...	100 "

When a blue image will appear on a white or blueish ground, if the development is sufficiently prolonged. The parts protected by the black lines being still in the ferric state will be precipitated by the ferrocyanide as prussian blue [$Fe_4(FeCy_6)_3$] while the unprotected parts, being reduced to the ferrous state, will form a *white* precipitate which absorbs oxygen from the air and speedily turns blue if not removed. If the exposure has been too short, all the per-chloride will not be reduced and blue spots will appear on the ground, but if too long, the image itself will be somewhat faint, owing to a partial reduction under the lines, and will require an exceedingly long development. When the image is sufficiently developed, the print is removed and washed in an abundance of clean water, to remove the white precipitate, after which it is put for a few minutes in a bath of

Hydrochloric acid, ... 1 part.
Water, ... 10 "

which will deepen the blue picture and whiten the backgrounnd. After washing for some time, the print can be dried and are then finished. This process is hardly applicable on a large scale, as it requires such care and nicety of execution to attain desirable results, that it conld not be trusted to any but experienced hands. If the paper, after exposure, had been put in a bath of

Red prussiate of potash ($K_6Fe_2Cy_{12}$), . . 25 parts.
Water, ... 100 "

a reversed picture would have been obtained, having white lines on a blue ground, owing to the fact that the unprotected parts being reduced to the ferrous state, would be precipitated by the ferricyanide as Turnbull's blue ($Fe_3Fe_2Cy_{12}$), while the protected lines would remain unchanged, so that when washed in water the per-chloride would be dissolved, giving white lines on a blue ground which would be further intensified by the acid bath. The name of cynotype was given to the latter process by its discoverer, Sir John Herschel. He also developed, on a dilute neutral solution of gold, tri-chloride getting a purple picture to which he gave the name of chrysotype. Any other per-salt of iron could be used as a sensitizer and developed on the ferrocyanide bath with the same result.

Blue Process.

The process which is most used in America, and which has been largely adopted by our manufacturers, is known as the blue process. The drawings are reproduced in white lines on a blue ground, and I understand the paper is sold in the market already sensitized, although it can be prepared cheaper and just as well as the bought article. Almost any heavy well-glazed printing paper will answer the purpose, but, as this is the only expense, a good quality should be used. The sensitizing bath consists of

a. Citrate of iron and ammonia, ... 1 part.
Clear water, ... 4 "
b. Red prussiate of potash, ... 1 "
Water, ... 6 "

The two solutions are dissolved separately, and preferably at the ordinary temperature; when in complete solution they are mixed, and

kept in a yellow bottle, or carefully excluded from the light, which would cause a blue precipitate. If the paper is not sufficiently sized, gum or gelatine should be added to give it body and prevent the liquid from soaking through. The sensitizing is performed as follows, in non-actinic light: The sheet of paper, cut to the required size, is pinned to a clean board; some of the solution is poured into a vessel, and the paper painted with it by means of a soft camel's hair brush three inches wide. The brush is dipped into the solution and the paper completely moistened in one direction; then, without removing the liquid, it is smoothed until no streaks or lines appear. Some prefer to use a sponge, but this causes uneven spots, and mars the beauty of the picture. In this way a very little solution will cover quite a large surface. Before putting the brush away it must be carefully cleaned. The paper is unpinned, hung upon a line, and when dry will keep a long time in the dark. It should be a brass-yellow color when rightly prepared. To make a copy, the drawing, on tracing cloth, is put into the printing frame, as usual, with a sensitive sheet, and exposed to sun light for six to ten minutes, or to diffused light for one to two hours. The double salt is reduced to the ferrous state where the light strikes it and immediately combines with the red prussiate present, to form Turnbull's blue, while the protected parts remain unchanged. The exposure should be continued, until, on opening the frame, the white lines have almost disappeared and the back ground is gravish-green. The sheet may also be exposed on a board padded with flannel, over which is placed a sheet of plate glass, but this requires to be always horizontal, and needs more apparatus than it would cost to get a regular frame. When exposure is finished the print is removed, and put immediately into a tank of running water, when the lines will become white (unless over-exposed or not in contact), while the ground becomes dark blue. After sufficient washing, the ground can be improved by transferring to a bath of

Hydrochloric acid, ...	5 parts.
Water, ...	100 "

when it must be again thoroughly washed, and then dried. The color always darkens on drying, and prints that would otherwise be under-exposed have very beautiful light blue ground.

This process has become the favorite one, owing to its great simplicity, and the ease with which any one can work it; the objections to it

are: the length of exposure, especially on cloudy days, and the impossibility of copying drawings from anything but tracing cloth or paper. In very large sheets the fine lines are apt to be reduced, thus making the picture somewhat uncertain in parts. If, instead of mixing the solutions, the paper had been sensitized with the citrate bath and then exposed, the reduction would have been very rapid (fifteen or thirty seconds), as this is the most sensitive salt of iron. The picture could then be developed in the ferricyanide bath, and finished as described; but in this case it is better to sacrifice sensitiveness to convenience. The other double salts could be used to replace the citrate, but they require a longer exposure.

Uranium.

The salts of uranium are affected similarly to those of iron, but they offer no advantages over the iron salts, and are besides very expensive. Those who desire to try them may use the following formulas.

A good quality of paper must be taken and sensitized by floating for six or eight minutes on a solution of

Uranic nitrate,	1 part.
Dist. water,	60 "

When dry the paper is exposed under a drawing for ten or fifteen minutes, and is then removed and developed by floating on

Ferricyanide of potassium,	1 part.
Water,	250 "
Nitric acid,	2 drops.

In about five minutes a brown picture will appear, which is fixed by washing in slightly acidulated water.

To produce a gray picture the print is floated on a bath of

Silver nitrate,	1 part.
Water,	20 "
Acetic acid,	a trace.

The development is very rapid in this solution, being complete in thirty seconds, after which it must be taken out and thoroughly washed in clean water. Red, green or violet pictures may also be produced, by developing on ferrocyanide of potassium, perchloride of iron, or chloride of gold.

Chromium.

The fourth and last salts are those of chromium, only two of which are commonly used, namely, the bi-chromates of potassium and ammonium. These form the basis for a number of valuable processes, one of which is at present attracting much attention in Germany, where it has been carried to a high state of perfection in the reproduction of drawings and fine engravings. It is called the

Aniline Process.

This was invented by Mr. Willis in 1864. It depends on the fact that when potassium bi-chromate, in the presence of organic matter, is exposed to the action of light, free chromic acid is formed and the protected parts, which still remain as bichromate, form aniline colors when exposed to the vapors of aniline salts. The process, in detail, consists of the following operations:

(1) Sensitizing the paper.
(2) Exposing.
(3) Fuming.
(4) Washing.

(1) *Sensitizing.*

The best Saxe paper must be used, as no other will give satisfactory results. The sensitizing solution consists of

Potassium bi-chromate, ...	1 part.
Phosphoric acid, sp. gr. 1·124, .	8 to 10 "
Distilled water, ...	10 " 12 "

The paper, after being cut and the finest side selected for use, is pinned to a clean, flat board. Some of the solution is poured into a dish and the paper is sensitized by means of a stiff brush, about one inch wide, which is dipped into the liquid and then painted on the paper, first lengthwise and afterwards across, without renewing the liquid on the brush. Finally, a soft camel's-hair brush, about three inches wide, is used to remove all superfluous liquid, and smooth out any streaks left by the first brushing. The solution may also be applied with a soft sponge, but the first method is preferable as the fingers are not then brought into contact with the bi-chromate which is a violent poison. The sheet is now hung up and allowed to dry slowly, it being complete in from fifteen to twenty minutes. The operation should be performed in a dark room lighted with a lamp having a yellow chimney. Ordi-

nary yellow light is not sufficiently non-actinic, owing to the extreme sensitiveness of the paper, which is easily affected by the least light. When dry, it may be preserved for some time unaltered in the dark. The brushes should be thoroughly washed each time they are used, and carefully protected from dirt.

(2) *Exposing.*

The prepared paper is now placed in the printing frame, under the tracing, covered with a black cloth and carried into the sunlight. The length of exposure will vary with the time of the year; in summer, being about twenty seconds, and in winter, forty seconds. The surest method is to use Vogel's photometer and carry the exposure to sixteen degrees, but as this cannot always be obtained, experiments may be made to determine it. This is the most important part of the whole process, because undue exposure will not reduce the bi-chromate sufficiently, and over exposure renders the paper less liable to form aniline colors. When the paper is rightly prepared, it should be a light yellow color and after exposure, on opening the frame, a faint yellow picture will be observed on a greenish ground.

(3) *Fuming.*

When the exposure is judged sufficient, the cloth is replaced and the frame carried back into the dark-room, where it is opened, the picture removed, and pinned to the lid of a fuming box. The box is provided with a sheet of glass, on which is blotting paper soaked with a solution of

Aniline oil, ...	1 part.
Benzine, ...	10 "

and which can be lowered or raised at pleasure by means of cross pieces of wood at different heights. It is allowed to remain thirty minutes, when the picture, if rightly exposed, will be sufficiently developed and will show a dark brown or purple picture on a gray ground. If the image is rather faint, it should be fumed longer.

(4) *Washing.*

On taking out the print, it must be washed for some time in at least four changes of water, when the colors will be fast, and, after drying, the picture is finished. Great care must be taken not to handle the sensitive paper any more than is absolutely necessary, and then only

with perfectly clean hands; also to perform *all* the operations in absolutely non-actinic light.

In review, we conclude that, in point of cheapness, the blue process has the preference; but, for certainty of results and general reliability, under all conditions, the silver process is the best. I should, therefore, recommend it in all cases where first cost will not be a consideration compared to convenience and saving of time.

Jan. 2, 1879.

ADDENDA TO A PAPER*—"COAL GAS ENGINEERING."

The following summary of the relations of constituents of coal gas may prove useful for reference in many instances:

Table of percentages, by weight, of the Constituents of Coal Gas.

			H, Hydrogen.	C, Carbon.	O, Oxygen.	N, Nitrogen.
H	Hydrogen,	= 7·3171	= 7·3171			
CH_4	Marsh gas,	= 47·2861	=11·8215	=35·4646		
C_2H_4	Olefiant gas,	= 18·4407	= 3·0734	=15·3673		
CO	Carbonic oxide,	= 13·6331		= 5·8428	= 7·7903	
CO_2	Carbonic acid,	= 7·1620		= 1·9533	= 5·2087	
4N+O	Air,	= 4·6995			= 1·0443	=3·6552
H_2O	Vapor of water,	= 1·4615	= 0·1624		= 1·2991	
	Coal gas,	=100.	=22·3744	=58·6280	=15·3424	=3·6552

Table of weight of Constituents of 100 *cubic feet of Coal Gas in pounds and decimals.*

			H, Hydrogen.	C, Carbon.	O, Oxygen.	N, Nitrogen.
H	Hydrogen,	=0·23340	=0·23340			
CH_4	Marsh gas,	=1·50835	=0·37709	=1·13126		
C_2H_4	Olefiant gas,	=0·58823	=0·08403	=0·50420		
CO	Carbonic oxide,	=0·48488		=0·18638	=0·24850	
CO_2	Carbonic acid,	=0·22846		=0·06231	=0·16615	
4N+O	Air,	=0·14995			=0·03332	=0·11663
H_2O	Vapor of water,	=0·04662	=0·00518		=0·04144	
	Coal gas,	=3·18989	=0·69970	=1·88415	=0·48941	=0·11663

The table at the end of article on Coal Gas Engineering, in the June number of the JOURNAL of last year, should be corrected to obviate the errors in setting up:

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* JOURNAL OF THE FRANKLIN INSTITUTE for April, 1878, by Robt. Briggs, C. E.

Table of Relative Value of Standards used in Photometric Measurement.

One standard gas burner, per hour,	Total weight, lbs.	Ratios of weight of material consumed to give equal light.
equals { 5 cu. ft. coal gas, of English quality = 0·426 spec. grav. = 0·0319 lbs. at 70° }	0·1595	1·000
equals { 15 standard candles, each burning 120 grains spermeceti = 0·09259 lbs. }	0·2671	1·634
equals { $\frac{15}{9·6}$ = 1·5625 carcel lamps, each burning 42 grams = 0·09259 lbs. colza oil }	0·1447	0·908

A NEW CALORIMETER.

By W. L. Hooper, A.M.

There seem to me several objectionable points in the construction of the ordinary calorimeter: First, although the surfaces of the instrument are very poor radiators, the material of the walls is generally an excellent conductor; secondly, the air-space between the walls is entirely open so that much heat must be carried off by convection currents in the air. I have accordingly constructed an instrument in which both imperfections seem to be remedied. It consists of two ordinary glass beakers, one of which is placed inside of the other, supported by a rim of bright tin. Upon the outside of the inner beaker, and upon the inside of the outer, about four-fifths of the height from the bottom, a film of metallic silver is deposited by the ordinary process of silvering glass specula. It was hoped that this confined air-space, enclosed on *every* side by the very worst of radiators and absorbers, themselves non-conductors, would furnish an excellent barrier against the escape of heat from the liquid in the instrument. How far this hope was realized may be seen from the table below, in which the ordinary metallic calorimeter and my instrument are compared. The two instruments were placed side by side in a room free from draughts, and into each was poured 500 cc. of boiling water. The readings of a thermometer placed in each were then taken, the thermometer in my instrument being read just ten seconds before the other:

New Calorimeter. Time.				Old Calorimeter. Time.		
h.	m.	sec.	Temp. °	h.	m.	Temp. °
3	2	50	93·4	3	3	93
3	5	50	88·7	3	6	85
3	7	50	86	3	8	81·3
3	9	50	83·5	3	10	78
3	11	50	81·1	3	12	75
3	13	50	79	3	14	72·5
3	15	50	77	3	16	70
3	17	50	75·1	3	18	68
3	19	50	73·1	3	20	66
3	24	50	69·2	3	25	61·8
3	34	50	64	3	35	55·4
3	54	50	55·3	3	55	46·7
4	9	50	50·2	4	10	43

It cannot be necessary to study the table very closely to observe the superiority of my instrument as a non-radiator. During the first three minutes, the water in the metallic calorimeter fell eight degrees in temperature; in the same time, the temperature in my calorimeter fell less than five degrees. Glancing down the columns, we find that while my instrument was parting with thirty degrees of heat, the temperature in the other had fallen nearly forty degrees.

While the new instrument has the disadvantage of being easily broken, it has the compensating advantage of being very easily made, whenever access may be had to a chemical or physical laboratory.

Bloomfield School, Harvard, Mass., Dec. 24, 1878.

Large Frost-Crystals.—At the meteorological observatory on the summit of the Puy-de-Dome, great difficulties are ofted experienced from the heavy deposits of hoar-frost. The telegraph wires often receive a coating of more than 20 cm. (7·87 inches) in thickness; the lightning rods have a much thicker covering, and on the windward side of the building ice-crystals sometimes form 85 cm. (33·47 inches) in length with their points toward the wind. Various plans have been tried to get rid of the inconvenience, but without success.—*La Nature.*

C.

Chemical Constitution of Wool.—P. Schützenberger has published analyses of various samples of wool, from which he deduces the chemical formula $C_{240}H_{381}N_{70}O_{77}S_6$.—*Comptes Rendus.* C.

Temperature of the Sun.—F. Rosetti has published the results of an extensive series of investigations, from which he estimates the temperature of the sun at between 12,000° and 20,000° (21,632 and 36,032°F.).—*Il Nuovo Cim.* C.

Metallic Packings.—J. Strieder, of Elberfeld, uses tubes of lead or some soft metallic alloy, filled with hemp, cotton or some other suitable vegetable material. These tubes can be prepared of great length and cut to fit any given requirement. The ends may be either soldered together or forced into close contact. The convenience, durability and cheapness of this packing are especial recommendations.—*Dingler's Pol. Jour.* C.

Pyrometers.—F. Fischer publi hes the results of some comparisons of his small calorimeter with Steinle and Hartung's graphite-pyrometer, Siemens' electric pyrometer and Geissler's normal quicksilver thermometer. The instruments all agreed satisfactorily for temperatures below 450° (842°F.). Above that point Siemens and Fischer agreed, but the graphite indications were higher. When Siemens' marked 623° (1153°F.) the graphite gave 755° (1391°F.). The graphite, however, was more sensitive than the electric pyrometer.—*Dingler's Journal.* C.

Excavations and Foundations in Sand.—M. Plocq has published an interesting note upon the recent harbor improvements at Dunkerque and Gravelines. There are ten sluices for controlling the fresh and salt waters of the districts, for various purposes of maritime and domestic economy, as well as for the wants of the military service and for defensive operations in time of war. The sluices are built in a soil which is wholly made up of a pure sand, of flour-like fineness, reaching to a depth of 15 or 20 metres (16·4 to 21·9 yds.) below the lowest tidal levels. The works were all executed by the help of coffer dams, in preference to dredging, and the preparations were so thorough that it was always easy to work in dry sand even at the lowest foundation levels. The total cost was less than half what it would have been by the old method of dredging, and the saving of time was in about the same ratio.—*Ann. des Ponts et Chauss.* C.

New Electric Phenomenon.—About ten years ago, Govi found that the interior volume of a Leyden jar seemed to expand during a charge, and he attributed the phenomenon to a contraction of the liquid which it contained. Duter has now shown that the effect is due to a temporary expansion of the dielectric envelope.—*Comptes Rendus.* C.

New Mode of Cementing Metal to Glass.—Mix two parts of finely powdered litharge and one part of fine white lead; mix three parts of boiled linseed oil with one part of copal varnish; stir the powder into the liquid until it has the consistency of a stiff dough. Spread the cement on the metal, press it against the glass, and scrape off the surplus. It dries quickly and is remarkably tenacious.—*Fortschr. der Zeit.* C.

Spartan Soups.—Most persons have heard of the *black broth*, in which the Lacedemonians dipped their bread, and which they preferred to the most savory dishes. Meursius thinks that it was the water in which pork had been boiled, with the addition of vinegar and salt, the only seasonings which they employed. Ricard thinks it was a soup, and says that they made another kind with eels, which they called *white soup.*—*La Nature.* C.

Greenland Native Iron.—Prof. J. Lawrence Smith has presented a memoir to the French Academy upon the remarkable deposits of native iron in the basaltic beds of Greenland. After long study, he concludes that the iron is of terrestrial origin; that it is often so closely joined to the basalt that feldspathic and other crystals penetrate the iron, and that the iron is probably a secondary product formed by the decomposing action of lignite beds and other organic matters, which have been pierced by the immense basaltic dykes.—*Comptes Rendus.* C.

Giffard's Success.—Giffard made 1000 captive ascensions, on 72 days, taking 3,500 passengers, without the least accident, receiving 839,555 francs, distributing 35,000 commemorative medals at a cost of 44,000 francs, burning 150,000 kilogrammes (147·63 long tons) of coal under the boilers. He has solved some problems of great importance: the preservation of hydrogen for a long period in an impermeable tissue, the preparation of that gas on an enormous scale, the new construction of all the parts of a balloon on a plan which prepares the way for building true aerial ships.—*G. Tissandier.* C.

Earth Ventilation.—Fischer and Stiehl propose to draw air for ventilation through a system of tubes buried about 3 metres (9·84 ft.) in the ground. By this means the air would be warmed 8 or 9 degrees (14·4° or 16·2°F.) in winter and cooled 12 or 13° (26.6° or 23·4°F.) in summer.—*Dingler's Journal.* C.

Nitrous Oxide Under Pressure.—P. Bert finds that by placing a patient in an apparatus where the pressure can be increased to two atmospheres, nitrous oxide can be administered so as to produce continued anæsthesis, while the blood receives its normal supply of oxygen and the normal conditions of respiration are maintained. From various experiments on animals, he thinks that gas administered in this way will be harmless, however much the insensibility may be prolonged.—*Comptes Rendus.* C.

Trial of a Corliss Engine.—A commission for experimenting with an Alsatian-built Corliss engine, has made a report in which it concludes: (1) That in order to secure the best results, the engine should be worked to its maximum capacity. (2) The economy of the steam-jacket increases as the load diminishes. (3) The clearing of the jacket should be thorough, but without wasting steam. (4) The warming of the piston is sometimes economical, but the saving, in ordinary cases, is not sufficient to pay for the necessary complication of machinery. —*Bull. de la Soc. Ind.* C.

Saint-Gothard Tunnel.—The small bronze turbines, which make 155 million turns per annum, after four or five years' service, require but slight repairs. Turbines of iron and steel, under the same pressure, do not last over a year. The 16 air-compressors supply air enough, under a pressure of 8 atmospheres, to supply 18 to 20 drills and to ventilate thoroughly all the tunnel, of which about 8 miles has already been bored. On each side there are, night and day, many hundreds of workmen, as many lamps, and about 600 pounds of dynamite are used daily. The financial difficulties of the company are connected with other portions of the line. The works of the tunnel have not been interrupted a single day for six years, and the original estimates will probably not be exceeded, although many unforeseen obstacles have been encountered. The tunnel will probably be finished within eight years from its commencement. The stipulated time was nine years.—*Comptes Rendus.* C.

Vesuvian Railways.—Concessions have been granted to two rival companies for constructing railways to the summit of Vesuvius, and it is expected that both routes will be rapidly pushed to completion. In many places the sleepers will be supported by columns.—*Les Mondes.* C.

Indication of Water Level in Reservoirs.—M. Decondon, Engineer, Paris, has constructed a very ingenious apparatus for indicating, at any distance, the level of water in a reservoir. He places a bell-shaped casting, mouth downwards, in the reservoir, resting on the bottom and partially filled with air. At the top a tube leads to any convenient place, where it is connected with a manometer which is constructed similar to the aneroid barometer and which is so sensitive that it indicates the slightest difference between the water level in the bell and in the reservoir, owing to the pressure of the enclosed air, which will support a column of water equal to this difference. As the apparatus acts independently of the atmospheric pressure, there will be a slight error, equal to the height of the water column in the bell. But this may be greatly reduced by making the latter very large and flat.—*Wochenschrift Oest. Ing. and Arch't Vereins.* P.

New Plan for Filling Gas Meters.—The chemical laboratories of Jacobsohn and Brunje, at Leopold's Hall, near Stassfurt, Germany, have introduced a new fluid for filling wet gas meters, composed mainly of a solution of chloride of magnesium. The meter of the Royal Polytechnic Institute, at Hanover, was filled, Dec. 8th, 1877, with 142 litres of the same, of a spec. gr. of 1·201. By the 15th the contents had increased by 1·5 litres and the spec. gr. was 1·190. Examination at different dates showed that:

On Dec. 21, 1877, the spec. gr. was							1·181
" Jan. 20, 1878,	"	"	"				1·182
" Mar. 3,	"	"	"	"			1·179
" June 1,	"	"	"	"			1·178
" July 15,	"	"	"	"			1·174

On July 15th, 1878, the meter was opened and the solution analyzed. No trace of a foreign material (iron or tin) was found, but it contained in 100 cubic centimeters 0·0214 grammes of NH_3 (ammonia) abstracted from the passing gas. A portion of the solution was cooled to 10° without freezing. During the whole time no replenishing had been necessary.—*Journal für Gasbeleuchtung, etc.* P.

Franklin Institute.

HALL OF THE INSTITUTE, Jan. 15th, 1879.

The stated meeting was held at 8'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 174 members and 63 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 18 persons were elected members of the Institute, and reported also the following donations to the Library.

Annual Report of the Hartford Steam Boiler Inspection and Insurance Company, Dec. 31, 1877. Hartford, 1878.
From the Company.

Annual Report of the Secretary of the Interior for year ending June 30, 1878. Washington, 1878. From the Secretary.

Annual Report of the Treasurer of the United States to Secretary of Treasury for year ending June 30, 1878. From the Secretary.

Electric Constitution of our Solar System. By Jacob Ennis. Philadelphia, 1878.

Elements of Sidereal Astronomy. By Jacob Ennis. Philadelphia, 1878.

Physical and Mathematical Principles of the Nebular Theory. By Jacob Ennis. London, 1878.

Origin of Power which causes Stellar Radiations. By Jacob Ennis. London, 1878. From the Author.

Fifty-eighth Annual Report of the Managers of the Apprentices Library Company. Philadelphia, 1878. From the Company.

Proceedings of the Tenth and Eleventh Annual Conventions of the American Master Mechanics' Association, Cincinnati, 1877 and 1878.
From the Association.

Quarterly Weather Report of the Meteorological Office. Part 3. July—September, 1875. London, 1878.
From the Meteorological Office.

Minutes of Proceedings of the Institution of Civil Engineers. Vols. 53 and 54. London, 1878. From the Institution.

Third Annual Report of the Water Commissioners of the City of Lowell, 1873.

The President then presented and read the following

Annual Report of the Board of Managers.

Your Board of Managers respectfully submits the following Report for the year 1878:

Members.—During the year 98 persons were elected members of the Institute, and 53 have resigned membership.

By death the Institute has lost four estimable life members, namely, Mr. Wm. Welsh, Mr. Bloomfield H. Moore, Mr. Thos. H. Powers and Mr. L. A. Godey.

Treasurer's Report.—The Treasurer's Report, which will be presented to the Institute this evening, exhibits the following summary:

Receipts.

Balance on hand Jan. 1st, 1878,		$1,809.48
Railway Equipment Bonds paid off,	$3,000.00	
Bloomfield Moore Fund held in trust for the improvement of the Library,	10,000.00	
		13,000.00
Receipts from ordinary sources of income,		9,710.11
		$24,519.59

Payments.

Bloomfield Moore Fund deposited,	$10,000.00
Payments for ordinary expenses,	11,501.42
Balance in hand Dec. 31, 1878,	3,018.17
	$24,519.59

It will thus be seen that the

Ordinary expenses were,	$11,501.42
" receipts,	9,710.11
Exhibiting a deficiency of	$ 1,791.31

which was occasioned by the continued defalcation in payment of the Bonds of the City of Pittsburg, and by other manifestations of the hardness of the times.

The Journal of the Institute has been issued regularly during the past year, under the direction of the Committee on Publication, with the assistance of the Secretary—an arrangement entered into in the early part of 1877, and which has proved very satisfactory.

The large number of articles containing the results of original work, by able investigators, which have appeared in its pages during the past

year, have fully sustained its rank among the leading technological journals, as is evidenced by the amount of matter reprinted from it, both in home and foreign journals.

The deficit in its accounts for the past year was reduced to a comparatively small sum, and it is confidently hoped that with the continued assistance of its valued contributors, and the increased support of members and friends of the Institute, which will come with the revival of the industrial interest of the country, the JOURNAL will be entirely self-supporting.

Drawing School.—At the close of the spring term of the Drawing School, Prof. L. M. Haupt found himself compelled, by pressure of other duties, to resign its charge, greatly to the regret of the Board.

The school was reorganized, however, in the autumn by Mr. Philip Pistor, M. E., and there was instituted a regular course of instruction, extending over two years, commencing with the more important elementary problems in plane geometrical drawing, and covering so much of descriptive geometry and orthographic and isometric projection, as are necessary to a complete knowledge of mechanical, architectural and topographical drawing.

The instruction in free hand drawing was discontinued, except as applied to sketches of machines, etc., to be used in making scale drawing and some exercises in the different orders of architecture; leaving all the instruction of purely ornamental and decorative character to other well-known institutions in the city.

The method of teaching adopted omits almost entirely the use of flat copies, depending principally upon blackboard illustrations and exercises in drawing from models.

While this course was strongly recommended to all the pupils, those sufficiently advanced had the opportunity of electing to take special instruction in some branch of more immediate importance to themselves.

The results of the first quarter have been very satisfactory, nearly all the pupils choosing the regular course, and their advance has been very encouraging.

This is an important branch of the work of the Institute, and the Board commends it to the earnest support of the members.

Lectures.—During the early part of the year (Jan. 3d to March 5th)

there were given six lectures by Prof. Elihu Thomson on the Correlation of Forces, three by Prof. P. E. Chase on the Manufacture of Bricks, Paper and Ink, and eight in the elementary series, by Prof. E. H. Bartley, on Chemistry.

In the arrangement for lectures this winter, there was provided a considerable number illustrating the useful applications of science, some of them being upon subjects now attracting a large degree of popular attention; of this class Prof. E. J. Houston delivered six during November and December.

During the same months Dr. W. H. Greene gave eight valuable lectures on Organic Chemistry.

The special rate of admission to the elementary lectures offered to non-members during the past two years was discontinued, as it was not made use of to any considerable extent.

Prof. Houston gave his usual lecture to children during Christmas week.

Phonography.—The class in phonography was continued under the charge of Mr. D. S. Holman, and the attendance during the year has been satisfactory.

Monthly Meetings.—The following statement of the attendance at the monthly meetings for the past three years shows a constantly increasing interest on the part of members and the public:

Years.	Members.	Visitors.
1876	1,060	112
1877	1,390	187
1878	1,425	400

Library.—The Board has been anxious for the improvement of the Library, and has appropriated to it all the funds available for that purpose, and beg to refer to the report of the Committee on its Condition, etc., which will be duly read.

By order of the Board,

R. E. Rogers, *President.*

After the reading, Dr. Rogers reminded the members that with this report he virtually ended his duties as President, and took occasion to thank them for their unvarying kindness toward him during the four years he had served the Institute, which, although old in years, is youthful in vigor and usefulness.

On motion of Mr. J. E. Mitchell, the order of business was suspended, and the following preamble and resolution were unanimously adopted:

WHEREAS, Our highly esteemed presiding officer, Dr. R. E. Rogers, having declined a re-election to the office he has so acceptably filled for the past four years, it is therefore

Resolved, That, in parting with Dr. Rogers, we desire to place on record our high appreciation of the courteous and impartial manner with which he has presided over our deliberations, as well as our appreciation of the valuable time and talents he has devoted to the service of this Institute, and we indulge the hope that in the future, as in the past, it may have the benefit of his extensive research and great experience.

The Library.

The Committtee on the Library respectfully report:

That during the year 1878, just passed, the gradual improvement of the Library has been continued.

We have added to our collection 806 volumes and 43 maps. Of the books, 455 are bound and 351 unbound.

Total number of bound volumes	Dec. 31, 1877,	13,104
" " " "	Dec. 31, 1878,	13,559
		455

During the past year we have arranged an exchange with the Royal Academy of Belgium, by which we are to receive a complete set of their Proceedings from the beginning, in return for a full copy of the JOURNAL of the Institute, with continued exchange.

Also, by the liberality of the French Government, we acquire all the volumes necessary to complete our collection of French Patents; also the *Annales des Ponts et Chaussées*, with many valuable Reports and the *Annales des Mines*, for which we are to send a full copy of the JOURNAL in exchange.

A continued and successful effort has been maintained to fill up the sets of some valuable serials. Although the result does not swell the Catalogue, it increases the value of the Library for reference.

The use of the Library by the members continues to increase with its improvement. During the past year 1,984 volumes have been

taken out by 265 members, while the use of the books in the Hall, both by reading and by making extracts, has been continued.

The Institute is aware that the Library is to receive the benefit of the liberal gift of $10,000 from Mrs. Bloomfield H. Moore, who thus desires to establish a memorial of her late husband.

No more fitting tribute to the memory of an honored member could have been designed, and the committee feel a peculiar satisfaction in accomplishing an object with which they sympathize so much.

Signed, by order of the Committee,

W. P. TATHAM, *Chairman.*

PHILADELPHIA, *Jan.* 6, 1879.

The representative of the Institute in the Pennsylvania Museum and School of Industrial Art presented the following report:

The progress made during the past year in the development of the original plan of the institution has greatly increased its usefulness.

The arrangement with the Permanent Exhibition Company was entered into on May 10th, 1877, by which that corporation was to receive all the entrance money and issue tickets admitting to both its building and Memorial Hall, and pay to the Museum corporation a fixed sum. The Exhibition Company having failed to pay over the money due, under their contract, the Museum was deprived of a considerable portion of its income, and in April last the agreement was cancelled and the receipts at Memorial Hall passed directly into the treasury of the Museum. Since that time the admissions have considerably fallen off, owing, no doubt, in a large degree to the difficulty of access to Memorial Hall from the street car lines on Elm avenue.

The experiment of opening the collections to the public on Sundays has proved satisfactory, both in the character of the visitors and in their number; more than 20 per cent. of the total admissions since April 6th having been on Sundays.

During the year the collections of English pottery and porcelain lent by Messrs. Daniell & Sons, of London; of specimens of enameled glass, of Brocart, and of pottery, by Deak, lent by Messrs. Landos & Co., of London, and of the collection of Spanish pottery and glass, lent by Signor Reano, of Madrid, were returned to their owners.

To fill the temporary void thus caused, the Trustees invited from citizens, the loan of suitable objects for exhibition, to which they

received a hearty response. The period of the loan terminated on Nov. 16th, but many of the depositors have allowed their objects to remain for an indefinite time.

The collection illustrative of the native productions and the manufactures of British India, loaned after the close of the Centennial Exhibition, has, through the kind offices of Sir Herbert B. Sanford, been presented to the Museum.

Other gifts have been received from private citizens, prominent among which is a cork model of the Temple of Neptune, at Pastum, sent from Naples by Mr. Fred'k Graff.

The Numismatic and Antiquarian Society of Philadelphia has deposited its valuable and extensive collection of coins, together with similar collections belonging to the American Philosophical Society, and the Library Company of Philadelphia.

During his visit to the Paris Exposition, the Secretary purchased a few specimens of art workmanship and a considerable number of books, on Industrial Art, for the Library.

The collection illustrative of mining and metallurgy, belonging to the American Institute of Mining Engineers, still remains on loan, and, from negotiations now pending, it is expected that the collection will soon be permanently deposited with the Museum.

During the last session of the Legislature an effort was made to obtain State aid in the work of the corporation, but it resulted only in an appropriation of $5,000 for the maintenance and repair of Memorial Hall, a sum considerably less than that actually expended for that purpose.

The provisions of the U. S. Tariff were found insufficient to admit free of duty many objects imported by educational institutions, and during the last session of Congress an amendment was made to the law, by which nearly all articles the Museum may wish to import will be admitted free, and which relieved a number of purchases made at the Centennial which up to that time were under bond.

The progress of the schools during the year has more than equalled the expectation of the Trustees. The instruction has been in the direction of self-help, and to instil into the minds of students the principles involved, rather than allowing them to learn by rote. The hours of attendance were changed at the commencement of the autumn term, requiring each class to be present only twice each week, instead

of each day, as before, thus enabling the same instructors to teach twice as many pupils. The number now attending regular classes is 200.

The art needle-work class has been continued with marked success as to the instruction given and the character of the work produced, although it has not been self-supporting. The number of free pupils is kept constantly at 25, and after they have acquired sufficient proficiency they are employed on orders at pay. In the management of these classes the Trustees have been greatly aided by the Advisory Committee of twelve ladies, who devote much time to the work.

So far the work of the different departments has been carried out as fully as means would permit, and the Trustees confidently appeal to the people of all classes for that financial aid necessary to complete what has been so well begun.

J. B. KNIGHT.

Profs. Houston and Thomson exhibited, in operation, two forms of their vibrating electric lamp, operated by currents produced by a dynamo-electric machine, also of their own design and construction.*

They also gave an illustration of the possibility of transmitting power for long distances, through small wires, by means of electrical currents. The currents of high electrio motive force generated by one machine were conveyed through two fine wires, of combined area of ·004 of an inch, to another machine, which in turn gave off considerable power.†

The tellers of the election held this day presented their report, and, in accordance therewith, the President declared the following members elected as officers and managers:

President, William P. Tatham.
Vice-President, Jas. E. Mitchell.
Secretary, J. B. Knight.
Treasurer, Fred'k Fraley.
Managers to serve three years, Hector Orr, R. E. Rogers, Elihu Thomson, Cyrus Chambers, Jr., Wm. V. McKean, Wm. Sellers, H. R. Heyl, J. Vaughan Merrick.

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* This machine will shortly be described in the JOURNAL.

† For demonstration of the principles involved, see page 36 ante.

Manager to serve two years, to fill vacancy, C. S. Heller.

Representative in the Board of Trustees of the Pennsylvania Museum and School of Industrial Art, J. B. Knight.

Dr. Rogers, the retiring President, then conducted his successor, Mr. Tatham, to the chair, and expressed his gratification in resigning it to one so earnest in promoting the work and interests of the Institute and skilful in administration.

Upon assuming the chair Mr. Tatham thanked the members for the honor so unanimously conferred upon him, and asked their indulgence for any deficiency that might arise from his want of experience as a presiding officer. He invoked their co-operation and assistance in promoting the usefulness and prosperity of the Institute; for prosperity and usefulness go hand in hand. He called attention to the facts that in 1824, when the Institute was founded, the city contained about one-sixth of its present population, and that within the first year thereafter there were over 600 members enrolled;* that of the largely increased number of inhabitants of Philadelphia we should now have as large a proportion of members as in the earlier years, and this he believed could be easily accomplished, if every member would call the attention of his friends to the advantages the Institute offers in its meetings, library, lectures, sections and committees, to all persons interested in the progress of science and the mechanic arts, whether as teachers or learners, or as desiring the benefit and instruction of others.

The Secretary's report embraced J. d'Auria's Steam Engine Governor;† and Meeker's Automatic Coin Cashier, to facilitate making change, consisting of a series of receptacles for coin of the various denominations, standing at an inclination from the perpendicular, and having at their lower ends a slide, which, when moved to the proper position, allows one piece of coin to drop out. The slides are marked with the denominations of the various coins contained in the receptacles, and are operated by passing the thumb upon an extension thereof projecting to a convenient distance, and the palm of the hand is at the same time held under to receive the coin as it drops out: Crawford's Automatic Cut-off for Water Pipes, consisting of a differential expansive thermometer, so connected to a cock at the lower end

* There were 637 members enrolled in 1824.

† A description of this governor will appear in the next number of the JOURNAL.